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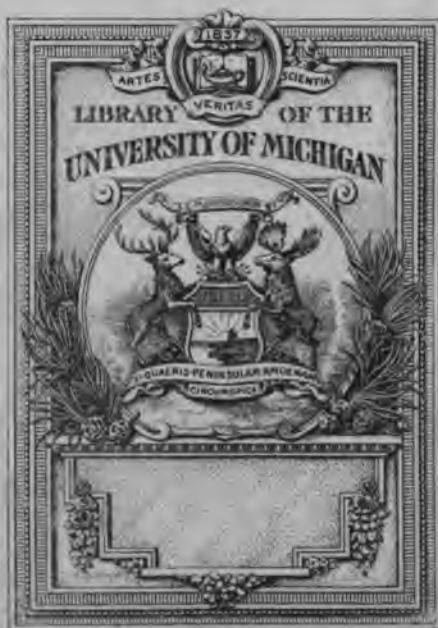




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THE
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Errata for Volume XXIX.

Page 137, third line, for "Upper Huronian" read upper Turonian.

Errata for Volume XXX.

- Page 60, sixth line from the bottom for "volume" read number.
 Page 90, after the first line add the words: should stand as valid.
 Page 116, fourteenth line from the bottom, for "cource" read source.
 Page 190, fourth line, for "feet" read inches.

THE
AMERICAN GEOLOGIST.

VOL. XXX.

JULY, 1902.

No. 1.

ORIGIN OF ESKERS.

By W. O. CROSBY, Boston, Mass.

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INTRODUCTION.

The discussion of the origin of eskers seems to have subsided almost as completely as the glacial streams by which, it is universally conceded, they were formed. This is particularly true as regards the main question which glacialists have, in recent years sought to determine,—*viz*: Were subglacial or superglacial streams the principal factors in the making of eskers? A large majority of geologists are resting in the belief that these winding ridges of glacial gravel are the product chiefly if not wholly of the subglacial drainage of the

ice-sheet. And in reopening this discussion, as one of the still unconverted adherents of the superglacial theory, my main purpose is to show that under normal conditions the deposits of gravel and sand formed in a superglacial channel may be let down upon *terra firma* without obliteration and without loss of the distinctive features of an esker. In this connection I appeal especially to basal melting and to the principle, first enunciated by Upham, that the ice beneath a superglacial river will be melted downward and the channel deepened by the water which saturates and flows through the deposit of gravel and sand constituting the embryo esker. But I also hope to reinforce these principal arguments by others which, if less cogent or less vital, are yet essential to a complete theory of eskers.

It is recognized by all that eskers must represent the waning stage of the ice-sheet; and probably the extent of basal melting during this stage is generally underestimated; but still few will question that it is to the surface melting or ablation of the ice that we must look for the main source of water for the glacial streams, whether superglacial or subglacial.

It is undoubtedly true that deposits which may be classed as eskers have been formed under a variety of conditions: in superglacial channels; in subglacial channels; in ice-walled, earth-bottomed canyons, open to the sky; and with or without the active agency of water. And all the theories are, no doubt, essential to a complete explanation of eskers, the main question now being as to their relative importance, or as to which best accounts for the more typical and important examples and has, therefore, the best claim to be regarded as *the* theory of eskers.

Evidence of Existing Glaciers and Ice-Sheets.

It must be conceded at the outset that nowhere have observations having any obvious bearing upon this problem been made upon existing icemasses which realize, even approximately, the essential conditions of the Pleistocene ice-sheet as it existed upon the plain country remote from mountainous tracts, where, chiefly, eskers are now found. In Alaska, we have, besides the Malaspina glacier, only alpine glaciers in lofty mountain valleys of high gradient; and the Malaspina

glacier, the type of piedmont glaciers, is simply a lake of ice existing at a level where permanent ice could not form, due to the confluence on the lowlands of the powerful alpine glaciers of the St. Elias range, and deriving its movement, in part at least, from the thrust of these tributary ice-streams. On Greenland, which appears to have mountainous borders with an inner lowland, we find a true ice-cap, with an area estimated by Peary at 600,000 square miles, and a maximum thickness of, probably, several thousand feet and possibly a mile or more; and it is well known that in the recent past this ice-cap, which has evidently passed its culmination or maximum stage, has covered the whole of Greenland and the islands which fringe its coast, extending, possibly, far into the adjoining seas. But observation, naturally, has been chiefly confined to the margins of the ice, and to the overflow portions of the great *mer de glace* descending as lobes and valley glaciers to and toward the coast, and, as in the case of the Malaspina glacier, to levels at which permanent ice can not form under existing climatic conditions.

In both Alaska and Greenland, the drainage of the ice is chiefly subglacial; and at many points powerful streams of water, carrying heavy burdens of detritus, are seen to issue from beneath the margins or extremities of the ice lobes, while the superficial streams, due to ablation of the upper surface of the ice, rarely if ever reach its margin, being swallowed by crevasses to form *moulins* and become tributary to, and the main sources of, subglacial rivers. In the case of the Malaspina glacier, the principal rivers discharging from its front or seaward margin undoubtedly have their sources high up in the valleys of the St. Elias range; and, as described by Russell,* are seen in several instances to pass beneath the upper margin of this great piedmont glacier, in well-formed, wide-mouthed tunnels, the subglacial course of such a stream as the Fountain or Yahtse being merely an incident of its history. But the main point, of course, is that we have here more indubitably than anywhere else ice-tunnels of considerable length—5 to 25 miles at least—occupied by large and rapid streams, the outlets of which are being obstructed and raised by the deposition of coarse detritus swept out of the tunnels by the torrents or dis-

* *Jour. Geol.*, 1, 240.

charged by the slow process of ablation from the frontal slope of the ice, the conditions thus favoring the aggrading or building up of the beds of the subglacial streams by still coarser detritus which the deepening water cannot urge to the outlet. In short, we appear to find here all the machinery usually regarded as essential to the subglacial origin of eskers.

But eskers are not a conspicuous feature of the land between the Malaspina glacier and the shore, across which the margin of the ice has recently receded—a tract which, though divided by the Sitkagi bluffs, aggregates nearly seventy miles in length. It is natural that it should be so, since, granting, for the sake of the argument, that ridge-like deposits of gravel may be formed in the earth-bottomed ice tunnels occupied by these impetuous subglacial streams, they must also inevitably be obliterated or buried by the agency of the same streams, as fast as they are exposed by the recession of the retaining walls of ice and brought within the zone of extremely rapid fluvial deposition, where the overloaded streams are building their detrital cones. In fact, although scores of subglacial streams are escaping from the southern margin of the Malaspina glacier, Russell has noted on this marginal plain, several hundred square miles in area, but one esker, or distinct ridge of gravel, which is clearly the product of deposition and not of erosion. This is on the north side of and parallel with Kame stream; and is described as a sharp ridge of well-rounded gravel which is seen in places to rest on an icy bed and was evidently deposited by a stream which flowed fully one hundred feet higher.* Again, it is said to date from a former stage when the waters flowed about one hundred feet higher than now and deposited a long ridge of gravel on the ice.† Having been formed on the ice, it is probably to be regarded as the product of a superglacial or englacial stream, and not of a subglacial stream, such as Kame stream is today.

It appears probable that the principal subglacial streams of the Malaspina glacier are but little constrained by the ice, or at least that their courses are conformable to the ground topography to the extent that they nowhere flow uphill; and quite certainly we may assume that they do not show the utter dis-

* *Am. Jour. Sci.* 143, p. 180.

† *Jour. Geol.* 1, p. 240.

regard of the topography observed in many eskers. In so far as the subglacial streams follow closely the axes of the ground valleys, their courses may be regarded as virtually fixed, and deposits formed in their channels cannot fail of obliteration or burial when uncovered by the recession of the ice; and the same fate will, of course, be shared by deposits formed in the ice-walled canyons in which the ice tunnels frequently terminate. In view of these considerations, it is certainly not surprising that truly subglacial eskers are not now coming into view through the shrinkage of this lake of ice. The piedmont glacier appears fairly comparable in this respect with the tributary alpine glaciers and with valley glaciers in general, including the Muir glacier and other ice-streams tributary to Glacier bay.

The only features suggestive of eskers yet noted in the detailed studies of the Muir glacier are the deposits described by Prof. Wright* as formed in certain ice tunnels near the thin, debris-covered margins of the glacier. These tunnels were abandoned by the subglacial streams which made them and subsequently filled by the sliding in of the superglacial detritus through holes in the roofs. Prof. Wright says, "In numerous places the roof of this tunnel (which is 25 to 30 feet high) has broken in, and the tunnel itself is now deserted for some distance by the stream, so that the debris (which overlies the ice to a depth in some places of 15 to 20 feet) is caving down into the bed of the old tunnel as the edges of ice melt away, thus forming a tortuous ridge, with projecting knolls where the funnels into the tunnel are oldest and largest. At the same time the ice on the sides at some distance from the tunnel, where the superficial debris was thinner, has melted down much below the level of that which was protected by the thicker deposit; and so the debris is sliding down the sides as well as into the tunnel through the center. Thus three ridges approximately parallel are simultaneously forming—one in the middle of the tunnel and one on each side. When the ice has fully melted away, this debris will present all the complications of interlacing ridges with numerous kettle-holes and knobs characterizing the kames (eskers); and these will be approximately parallel with the line of glacial motion. The same condition

* *The Ice Age in North America*, p. 62.

of things exists about the head of the subglacial stream on the east side, also near the junction of the first branch glacier on the east with the main stream, as also about the mouth of the independent glacier shown on the map lower down on the west side of the inlet."

We have clearly indicated here a type of eskers in the formation of which running water is not an immediately active agent; and, moreover, at the time of their filling by superglacial detritus, the subglacial tunnels have become gorges open to the sky and the deposits are not in any proper sense subglacial. Undoubtedly this is a true explanation of some kame-like and hummocky forms of modified drift: and it appears that, in general, deposits formed under these conditions would be more properly classed as kames than as eskers: and no one, perhaps, supposes that the more typical eskers of New England and other districts covered by the Pleistocene ice-sheet have had this origin.

The search for eskers along the borders of the Greenland ice-cap and its dependent lobes or glaciers has been even more fruitless; and Chamberlin,* among recent competent observers in that field, has expressly noted the practical absence of this class of phenomena, attributing it chiefly to the inadequate drainage; but in part, also, to the fact that glacial streams are mainly lateral, coursing along the margins of the ice lobes, while medial tunnels of Alaskan and Alpine glaciers are wanting. According to Russell, the drainage of the glaciers of the Mt. St. Elias range, above their confluence with the Malaspina glacier, is, also, largely or chiefly by marginal streams, which, like the lateral moraines, unite at the lower ends of the mountain ridges and pass into or beneath the piedmont glacier.

Nowhere, apparently, have esker-like deposits been formed by the subglacial streams of Alpine glaciers, owing in part to the high gradients of the valleys, and in part to the paucity of detritus and the consequent absence of deposits at the lower end of the tunnels of sufficient volume to efficiently clog the outlets and lead to aggrading of the floors of the tunnels.

That observations on the existing ice of the northern hemisphere have made no important positive contributions to the theory of eskers, is, perhaps, not an overstatement. We may

* *Bull. Geol. Soc. Am.*, 6, 215.

fairly conclude, however, that the Antarctic ice-cap alone, of all existing ice masses, realizes at all closely, the conditions of the Pleistocene ice-sheets of northeastern North America and northwestern Europe; but unfortunately, no observations bearing upon the origin of eskers have been made here; and perhaps none are possible, since the margin of this greatest of living ice-sheets is, at most points, deeply submerged in the Antarctic ocean. Thus we are baffled at every point, and can only say that the testimony of existing ice is almost wholly negative, indicating only where and how eskers have not been formed.

Since, then, the formation of eskers has nowhere been observed, our only resource in seeking an explanation of this highly specialized type of drift is in a close study of existing examples, followed by a rigid testing of such working hypotheses as have been or may be suggested by the facts. Fortunately the principal facts are now well determined; but, although a good general agreement exists among glacialists as to what constitutes an esker, it appears advisable to briefly enumerate the main features before proceeding to a critical comparison of the rival hypotheses.

CHARACTERISTICS OF ESKERS.

Form.—The typical esker is a steep-sided, narrow-crested and more or less winding ridge, varying in height above the surrounding country up to 100 and even 150 feet. The lateral slopes usually approximate the maximum angle of repose for gravel. Although the crest is often of even height for considerable distances, it is more commonly diversified by cols and knolls; and not infrequently it widens into level-topped plateaus. Woodworth has shown that the variations in both height and breadth often find a reasonable explanation in the ratio of depth to breadth of the original deposit, before the disappearance of the retaining walls of ice.* Eskers rather rarely receive distinct tributaries; but they are often composite, splitting up into two or several ridges, which wind and anastomose, enclosing kettles and even large, irregular basins with floors of till and holding water; and occasionally an esker is double, consisting of two distinct but contiguous parallel ridges. The esker ridge may be uninterrupted for long distances, but is

* *Proc. Bost. Soc. Nat. Hist.*, xxvi, p. 197.

usually more or less discontinuous; and an esker system (to which Stone has proposed to restrict the name *osar*), embracing all the esker ridges referable to one glacial river or drainage system, may be of any length up to 100 and even 150 miles.

Composition and Structure.—Eskers consist chiefly of coarse, and often of very coarse, gravel, mingled or inter-stratified with which is usually much coarse sand, although the sand may be at times insufficient to fill the interstices between the pebbles and cobbles. The proportion of sand and the fineness of all the material are greatest in the wide, flat-topped portions of an esker, corresponding to lake-like expansions of the glacial stream; but even here fine sand and clay are of rare occurrence. The gravel is more or less rounded and water-worn, and includes a larger proportion of far-travelled material than do the adjacent masses of till or ground moraine. This is a necessary deduction from the fact that the esker drift has been transported by water as well as by ice; and it has been fully confirmed by observation. These materials are rudely, irregularly, and very often indistinctly, stratified; and a sort of anticlinal structure, due to lateral sliding and settling as the retaining walls of ice melted away, is a characteristic, though by no means a constant, feature. Boulders, sometimes of considerable size, are rather rarely found resting on the slopes of eskers, and more commonly partially or wholly imbedded. Also, eskers may be more or less completely buried by delta and overwash plains and valley terraces and flood plains, but never by till or ground moraine.

Topographic and Geologic Relations.—Eskers and esker systems or *osars*, unlike the terminal moraines of the great ice-sheet, exhibit a tendency to conform in trend with the movement of the ice as recorded in striae, the major axes of drumlins and boulder-trains; and this conformity is often surprisingly close. This means that while occurring chiefly, with other forms of modified drift, in valleys, eskers are to a good degree, independent of the topography and often do not hesitate to forsake or to cross at all angles, large and well-accentuated valleys, in order to adhere to their normal courses. They may thus rise to levels far above, and cross tracts quite free from, all other types of modified drift. But there is a limit to their topographic independence, as recently noted by Stone.*

* *U. S. G. S. Mon.*, xxxiv, p. 36.

He finds in Maine, where exists the finest and most extensive development of eskers on this continent, that while they freely climb slopes and cross ridges from one hundred to two hundred, and more rarely three hundred and four hundred feet in height above the ground on which they rest to the northward, they are constrained to follow still deeper valleys or wind around still higher hills, usually seeking the lowest gap in a ridge or water parting. Valley eskers are very rarely found in the true axis of the valley or resting on the lowest part of the till or bed-rock profile, even where, as often happens, the channel of the modern stream is remote from or well above the real bottom of the valley. But the normal position of the esker is lateral or along one side of the valley; and even the base of the esker is, not infrequently, well above, sometimes a hundred feet or more above, the level of the modern flood-plain, which may in turn overlies a great depth of modified drift. The indifference of eskers to the contours of the surfaces on which they rest is farther seen in the fact that they may appear first on one side of the valley, and then on the other, but rather rarely on both sides simultaneously; and the same continuous esker, broken only by the modern stream, may cross and recross the valley from side to side.

Eskers seldom, if ever, occupy channels in either the bed-rock or till which may reasonably be regarded as due to the erosive action of the streams that formed the eskers. And, in general, distinct evidence of erosion by esker streams is wanting, except, perhaps, in the notching of the protruding drumlins or other nunataks of the waning ice-sheet.

Eskers commonly terminate southward in the delta and overwash plains formed along the southern margin of the ice-sheet, and to these they hold the relation of tributaries or feeders; and an approximate agreement in height of these terminal deposits with the proximal portions of the eskers has often been noted. Also, eskers commonly widen as they approach the plains and merge gradually with the latter.

Probable Status of the Ice-Sheet During the Formation of Eskers.

That eskers were formed by glacial streams in, on or under the ice-sheet and during the waning stage of glaciation, when

this border area was rapidly disappearing through superglacial and subglacial ablation, are propositions accepted by all and requiring no argument here. Further, we may postulate, with Davis and other able students in this field, the stagnant condition of this marginal zone during the esker-forming period. In fact, a stationary ice-margin is a condition highly favorable, if not absolutely essential, to every theory of esker formation; and, as Davis has insisted, it is demanded by the highly irregular and fragmentary border of the ice of which we have conclusive proof in the distribution and outlines of the deposits formed upon or against it, and in the absence of evidence of glacial thrust.

In my paper on englacial drift,* I have accepted and elaborated Upham's idea that over the vast plain or peneplain tracts of the glaciated area the ice-sheet was developed primarily by accumulation and not by invasion, existing at first as a sedentary ice-cap, which gradually acquired motion as it gained in thickness and also as it was progressively overridden by the older and already active ice to the northward. Again, I see now, as five years ago, no escape from the conclusion, also first enunciated by Upham, that during the period of ice accumulation and of maximum glaciation, the entire volume of the drift, including both the preglacial detritus and all that due to glacial rending and abrasion, was englacial, or firmly frozen in the basal portion of the ice. This conclusion is absolutely demanded by the universal rectilinear striation of the bed-rock surface, and is inconsistent, so far as I can see, with no established facts. I have also shown, in the paper cited above, that the observations of Chamberlin and others in Greenland and elsewhere, indicate that an ice-sheet, in its progress across even a comparatively smooth surface, is subject to oblique shearing movements which tend to transfer the englacial drift to higher levels in the ice.

I hold now, even more strongly than when writing the paper on englacial drift, that the tendency to the elevation of the drift in the ice must have been powerfully augmented by the overriding of the sedentary margin of newly-formed ice, during every advance of the ice-sheet, and the overriding of the stagnant margin of the old and wasted ice during every

* *AMER. GEOL.*, 17, pp. 203-234.

recession of the ice-sheet. The essentially stagnant condition of the outer portion of the Malaspina glacier, with a thickness of at least a thousand feet and a fairly steep frontal slope, and feeling the thrust of the powerful alpine glaciers behind it, is an instructive fact, suggesting that during the waning of the Pleistocene ice-sheet by active ablation over a breadth of one to several hundred miles back from the margin, this wasted marginal zone must have gradually ceased to move; for it is inconceivable that the thrust of the thicker ice to the northward could induce forward movement in a comparatively thin sheet of ice resting upon a strongly dissected but approximately level peneplain. Overriding, or at least a vertical thickening of the ice along the northern edge of the stagnant zone, appears inevitable; and obviously this could not occur without a corresponding elevation of the englacial drift. In view of these considerations, it may, perhaps, reasonably be affirmed that observations on existing ice masses do not afford a safe criterion for a judgment as to the amount or the depth of the englacial drift in that portion of the ice-sheet which was the locus of esker formation.

During the period of maximum glaciation, when the drift was all englacial and glacial erosion of the bed-rock surface was most severe, there could have been no important subglacial drainage; for the basal contact of the ice was perfect and continuous, as indicated by the universality of striation beneath the till or ground moraine; and the temperature of the ice must have been, throughout its entire thickness, well below the freezing point, even after making allowance for the lowering of the freezing point by pressure; this reduction amounting approximately to one degree Cent. under a mile of ice. When, through the rise of the isogeotherms in the earth's crust, the basal temperature rose above the melting point of ice, the deposition of the ground moraine began; and the striation of the bed-rock surface must have ceased at the same time, for the striæ are everywhere essentially rectilinear, which is inconceivable as due to the movement of the ice over a bed of loose material. We thus reach the conclusion that effective basal melting did not begin until after the ice had so far wasted by superficial ablation that its flow began to be influenced by topographic reliefs of relatively slight value, after, for instance,

the trough of the Boston basin had deflected the basal portion of the ice decidedly to the eastward. This was the period of drumlin formation, which was, probably, closely followed by the esker and sand-plain period.

The absence of basal water during all but the latest stages of glaciation is easier to understand when we consider how low, probably, were the initial temperatures throughout the entire thickness of the ice-sheet, and the great depth of frost penetration into the ground beneath the ice. Nowhere, probably, within the range of observation at the present time are the conditions of the Pleistocene ice-sheet more nearly realized than in the interior of Greenland; and in this connection Nansen's experience in his memorable transit over the ice from the eastern to the western coast is of special interest. He says,* "Some of the temperatures which we experienced were far lower than the established meteorological laws would have led us to expect. The temperature on certain nights, September 12 and 14, probably fell, according to the calculations of professor Mohn, to -45° Cent. (-49° Fahr.), while the mean temperature of certain days, September 11-16, when we were about in the middle of the country, or a little to the west of the highest ridge, varied from -30° Cent. to -34° Cent. (-22° to -29° Fahr.). This is at least 20° Cent. (36° Fahr.) lower than anyone would have been justified in expecting, if he had based his calculations on accepted laws, taking for his data elevation above and distance from the sea, as well as the mean temperature of the neighboring coasts." Now, supposing similar climatic conditions to have prevailed during the entire period of the accumulation of the ice-sheet, and considering that the glaciation of Greenland is long past its maximum and the climate, therefore, probably somewhat ameliorated, we have indicated a degree of refrigeration in and under the ice which the slow upward flow of the terrestrial heat would require a long time to overcome. The low temperature of the ice is seen not to be necessarily inconsistent with flow through the medium of a granular structure, in accordance with the views of Klocke, Deeley, Fletcher, and others, as summarized by Upham,† when we consider that the progressive melting of a granule at one point and its growth at another point demand differential

* *The first crossing of Greenland*, vol. ii, p. 480.

† *AMNH. GEOL.*, 17, pp. 16-29.

flow of subglacial waters did not exist before the ice became stagnant, the only explanation that suggests itself being that while the ice was in motion it would cause the drift to rise and fill any channel opened above it, a principle which is not operative beneath alpine glaciers (and possibly not beneath the Malaspina glacier) because they have long since swept their channels free of drift.

Comparison of Hypotheses.

Although recognizing, as previously stated, that other explanations, such as the filling of abandoned channels by surface slide and wash, are entitled to some consideration, and that they are all, probably, essential to the complete theory of eskers, it is proposed in what follows to take account only of the two main hypotheses; *viz.*, that eskers have been formed by the active agency of subglacial streams, or of superglacial streams. And here, again, as already noted, it is merely a question of relative importance, since I hold with Davis and other advocates of the subglacial hypothesis that neither can wisely be discarded *in toto*. Subglacial tunnels are a reality at the present time and were, doubtless, to some extent a feature of the Pleistocene ice-sheet; and it would certainly be hazardous to deny that deposits formed in them have never escaped obliteration on the disappearance of the ice.

Superglacial Hypothesis.

This explanation of eskers assumes a stagnant, marginal zone of the ice-sheet at least one hundred miles in maximum width, practically free from crevasses, sufficiently wasted by ablation to be more or less abundantly covered by englacial drift which has become superglacial, with a general southward slope, and, toward the southern border at least, thin enough to reflect in its surface contours in some degree, the underlying topography, and even to permit the more prominent land forms to rise as nunataks above its surface. At the southern margin of the ice the elevation or grade of the superglacial stream finds a limit or control in a barrier of rock or till against which the ice may temporarily terminate, or in a body of standing water (a glacial lake) held against the ice by such a barrier in north-

above and subglacial streams below, competing for the englacial drift, of which, chiefly, eskers must be formed.

Undoubtedly, the very latest direct work of the ice-sheet, before its motion finally ceased, was the building of the drumlins. In the lee sides of a few drumlins a limited amount of gravel is interstratified with the till, the product, possibly, of superglacial streams falling through the ice at these points, since crevassing would, probably, occur as early where the ice bends over the summit of a drumlin as anywhere. At the same time the ice must have tended to draw away from the lee slopes and leave the vacant spaces in which gravel could be deposited by superglacial, but not possibly by subglacial streams. We do not discover, however, any such general intercalation of washed drift with the ground moraine, either in drumlins, or elsewhere, as to suggest that crevasses were a common feature of the ice just before it ceased to move; and of course, none could be formed after it became stationary. Again, it appears probable that when the ice was thick enough to override drumlins one hundred to several hundred feet in height, its thickness was too great to permit extensive crevassing, especially in view of the fact that the thickness essential to flow must increase rapidly with diminishing slope and increasing roughness of the ground or basal friction, and the farther fact that even alpine glaciers in relatively smooth and unobstructed valleys of high gradient, and seldom exceeding 500 to 1000 feet in thickness, are but little affected by crevasses, except in cascades, and laterally where they feel the friction of the valley walls. In this connection we may profitably note once more that the marginal portion of the Malaspina glacier, with a thickness of at least one thousand feet and a steep frontal slope, at the base of lofty mountains and feeling the thrust of powerful alpine glaciers, and absolutely nothing to hinder its free motion seaward across the sloping coastal plain, is practically motionless. These considerations clearly point to the conclusion that the Pleistocene ice-sheet on the highly dissected and rough peneplain surface of the greater part of the glaciated area, with only extremely low average gradients in any direction, and then often either to the northward or transverse to the glacial movement, must have been at least two thousand feet thick when it ceased to move, and too thick in general for effective crevassing, or the formation of crevasses extending from the top to the bottom of the ice.

Crevasses are the product of tensile stresses; and it is obvious that as, during the progressive cessation of its flow from the south northward, each portion or zone of the ice becomes stationary, the ice still in motion immediately to the northward will crowd focibly against it and tend to obliterate by compressive stresses any crevasses which may interrupt its continuity. Overriding, or even a local thickening of the ice, may not always accompany the cessation of flow; but it is certainly difficult to see how, in general, crevasses could survive the progressive loss of motion. We have a magnificent illustration of this process in the Malaspina glacier, which is practically free from crevasses and well endowed with persistent superglacial streams on its outer, drift-covered, marginal zone, although crevasses are a common feature of all the central and northern part of this great piedmont glacier, or at least common enough to prevent the development of any important superglacial streams; and we can also suppose that they are closed by pressure from the northward or clogged by superficial drift as the ice gradually ceases to flow. In fact, Russell says that many of the crevasses are filled with clear, blue water; and that they appear to be the scars left by rents in the tributary ice streams. Concerning the drainage of the Malaspina glacier, Stone says:* "For some reason the glacial streams have either formed no subglacial tunnels under a marginal zone of uncertain breadth, or the original tunnels have become blocked by ice or sediment or moraines so that the streams have been forced to form englacial tunnels, which become superglacial by the melting away of the overlying ice, and the streams continue such as they flow down the terminal ice slope. If the glacier continues to retreat, it seems probable that a ridge or series of ridges such as are now forming, and abandoned channels of these rivers, will be prolonged northward as far as the englacial channels reach. This furnishes an observational basis for the conclusion that during the retreat of the ice-sheet, wherever the ice was very stagnant and the subglacial streams found their tunnels choked near their outlets, they freely rose into englacial or superglacial channels." This is important testimony and all the more interesting as coming from a subglacialist. Surely, if a piedmont glacier on a narrow, sloping coastal plain, at the base of lofty

* *U. S. G. S., Mon.*, 34, pp. 421-422.

ward sloping valleys, or, less rigidly, in the detrital cone formed by the stream itself as it escapes from the ice. Whatever the character of the control, it determines for each superglacial stream a base level, towards which it must approximate, but below which it cannot cut its channel by merely mechanical erosive action. The stream discharging across the ragged, southern edge of the ice is but the trunk or main stem of a system, deriving both water and detritus from many tributaries as well as by the ablation of its banks. In fact, it holds so far essentially the same relation to the drift-covered ice that an ordinary stream does to the drift-covered bed-rock. The tributaries making large angles with the trunk channel, or not approximately agreeing with it in direction, will not share its high gradient; and in consequence their channels will not be deepened so rapidly, but will become hanging valleys in their relations to the main ice canyon. But as the floor of the latter approximates the base level, the higher gradient will be transferred to the tributaries, which must then, in large part, discharge their accumulated burdens of coarse detritus into the main channel and thus lead to its rapid clogging and aggrading. Only unimportant accumulations will remain in the channels of the approximately right-angled tributaries; and we are thus able to explain the practical absence of right-angled branching in eskers. In special cases the base level of the superglacial stream will be the surface of the ground on which the ice rests; and then the clogging and aggrading will take place in earth-bottomed canyons, the slow melting of the ice walls of which will complete the process and leave the eskers as we now see them. There is, apparently, no reason why, in the absence of a frontal barrier, existing independently of the glacial stream or through its agency, this simple explanation may not fairly be postulated. We are, however, especially concerned with the fate of the esker which finds itself at the end of the base-levelling process on a foundation of ice twenty, fifty, or possibly one hundred feet thick.

To begin with, it is, perhaps, improbable that the coarse detritus which lags behind as the grade diminishes and gradually clogs and aggrades the channel of the superglacial stream, will have sufficient depth and volume to form a typical esker, or an esker approximating in height the sand plain to

which it is tributary, as long as the floor of the ice-gorge is nowhere below the base level, or the level of the frontal barrier. Down to this level the gorge has been formed by the mechanical erosion or corrasion as well as by the chemical erosion or melting of the ice; and below this level corrasion is surely inoperative. But here Upham's suggestion of a farther deepening of the gorge by melting alone intervenes, and I hope to show that it will continue with increased rather than diminished efficiency.

Basal melting of the icesheet must be in constant progress, summer and winter, during this state and is possibly an important factor in letting down and indirectly deepening the deposits in the superglacial channels; while the even distribution of the effects due to this cause may safely be assumed. But the main question now is, will the superglacial channel persist, or retain its walls, until its bottom reaches the ground? In other words, will the melting of its floor beneath its increasing load of detritus keep pace with, or at least keep ahead of, the general ablation of the interstream surfaces? The familiar instances of medial moraines resting on ridges of ice and isolated boulders perched on pillars of ice, through the more rapid melting of the drift-free surface, seem to demand a negative answer. On the other hand, the innumerable well-like holes in the ice, noted by many observers, and varying from an inch to several feet in depth, and often containing nothing but the purest of water, although commonly a stone or a little sand, clay, or cosmic dust is seen resting on the bottom, point to an affirmative answer. These holes are usually explained, however, as dependent upon the absorption of the solar heat by a slight thickness of stony or earthy matter; whereas thicker masses protect the ice beneath from the solar radiation. The occasional absence of foreign matter indicates that this explanation is incomplete; and the lakelets described by Russell* as a common and characteristic feature of the moraine-covered marginal zone of the Malaspina glacier clearly demand a different explanation from that usually accepted for the relatively small holes; for the lakelets, which may be fifty to one hundred feet or more in depth, and are rarely more than one hundred feet in diameter, appearing to differ from the holes

* *Nat. Geol. Mag.*, vol. iii, p. 120

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* *Nat. Geol. Mag.*, vol. III, p. 120

only in size, contain considerable amounts of drift, and the thickness of the deposit in the bottom of each basin constantly increases, as fresh material slides in from the top and sides. Obviously, these narrow basins, with steep and sometimes vertical sides are formed by the downward melting of a cylinder of ice beneath a cover of drift so thick that we cannot think of it as sensibly warmed, and still less as penetrated, by the solar heat, especially as the turbid water usually completely covers the drift.

These contrasts and seeming contradictions are readily explained if we accept the standing water as an essential factor, and regard the detritus as secondary. Thin stones and particles of drift absorb heat and sink into the ice; and thicker stones and deposits may do the same if they chance to occupy water-tight depressions in the surface of the ice. A dry stone, if thin enough, transmits heat directly to the ice; but with a submerged stone the transmission is through the medium of the water. Hence as soon as the thin stone or deposit becomes submerged the thinness ceases to be an essential factor, and it is on a par with the thick stone or deposit. The normal temperature of the water is, of course, that of melting ice, or four degrees Cent. below its temperature of maximum density. The water absorbs some of the solar radiation directly; and it takes up promptly and completely the much larger amount of heat absorbed by the submerged or partially submerged detritus. As fast as the water gains in temperature it sinks to the bottom, displacing colder and lighter water, and expends its surplus heat in melting the ice. As has been noted by others, this principle explains the fact that the ice shores of the Malaspina lakelets are undercut below the water level, the ice, as stated by Russell, melting below the surface more rapidly than above, where it is exposed to the direct rays of the sun. The thickness of the deposit is no appreciable bar to the process, so long as the material is sensibly permeable; but, on the contrary, it enables the water warmed by contact with its surface to sink promptly and quickly to the underlying ice, and with increasing thickness the pressure co-operates by lowering the melting point; while with such torrential streams as must have been those in which normal eskers were formed, the conversion of mechanical energy into heat may not be neglected. A bed of

permeable gravel not only co-operates in the ways indicated, to favor the melting of its ice floor, but it must tend to conserve the heat and to prolong the time during which melting can take place.

In view of these considerations, there seems to be no escape from the conclusion that the ice-floor of a superglacial stream will be lowered by the superficial as well as by the basal melting of the ice; that the superficial melting will be more active and efficient in proportion to the extent of aggrading of the channel and the volume of stagnant water saturating the gravel; and that the stream will be lowered at least as rapidly as the interstream surfaces, because, while these are also, according to our initial assumption, covered with drift and thus protected from the direct action of the sun's rays, they lack the standing water essential to the effective indirect utilization of the solar radiation.

Obviously, the aggrading of the channel may continue during all the time that the deposit is being let down upon the ground, and the resulting esker will then conform in elevation with the terminal plain, at least as closely as eskers commonly do, and show the characteristic lack of sympathy with the ground topography. Should the stream be diverted to another course before the subsidence of its deposits is completed at all points, the process will continue without essential change, unless a crevasse should draw off the water saturating the gravel, the result being one of the eskers falling in whole or in part below the normal elevation. The exceptionally high points or knolls may, according to this hypothesis, represent the detritus discharged by hanging tributaries into the main canyon after the diversion of the headwaters from the latter. All the conditions favor vertical rather than lateral melting of the ice; and there is, apparently, no tendency to scatter the deposit in getting it down to the ground. At the same time all observed variations in width are fully provided for, and more especially the gradual widening which commonly marks the junction with the terminal plain. Certainly nothing is more probable than the widening of the ice canyon at its mouth in the thin and frayed or lobate southern margin of the ice, where its walls are bathed by a large body of standing water. Stone's maps* show

* *U. S. Geol. Surv., Mon., 34.*

that this terminal widening is a particularly characteristic feature of the great esker systems of Maine; and some even, of the subglacial tunnels of the Malaspina glacier become, at the last, canyons with rapidly diverging walls. The constant movement and re-adjustment of the deposit during the settling process keeps it loose and permeable, and enables the water to wash out some of the filling of the coarsest gravels and thus give rise to the open-work gravel specially noted by Davis.

In the quite exceptional case where crevasses or other accidents drain the esker channel before its subsidence is completed, the differential melting is likely to be reversed, the interstream surfaces going most rapidly because less protected from the sun's heat, the esker deposit is left on a ridge of ice, and, sliding down on both sides, gives rise to a double esker, of which I have noted several good examples in the vicinity of Boston.* The quite common failure of the esker to connect properly with its terminal plain, a weak place or break intervening, may be in part attributed to the deposition of the head of the plain over the sloping margin of the ice and the subsequent melting of the latter. And the very numerous instances of plains of all the various types without associated eskers or feeder channels are simply the cases where the superficial stream was diverted before its channel was base-levelled, and consequently before it was aggraded to any important extent. Finally, the lateral position characteristic of valley eskers follows naturally from the tendency of the ice, before it ceased flowing, to become concentrated in the valleys or along the lines of freest movement, giving rise to what were virtually valley glaciers with arched profiles in what may still have been at the surface a continuous ice-sheet, and possibly with lines of shearing between the free-moving ice and the relatively stagnant ice of the uplands. When the ice becomes wholly stagnant, these lateral lines of weakness and the arched profile still remain to influence the courses of superglacial streams.

Subglacial Hypothesis.

As formulated by Davis,† this explanation of eskers also assumes a stagnant and decayed marginal zone of the ice-sheet. The water resulting from the basal melting of the ice,

* *Occas. Papers, Boston Soc. Nat. Hist.*, iv, pp. 278-284.

† *Proc. Boston Soc. Nat. Hist.*, vol. xxv, pp. 477-479.

together with that due to superficial melting and becoming subglacial through the medium of crevasses, is gathered into streams which, it is stated, hold to meridional courses or, more exactly, conform with the general trend of the ice movement, in obedience to a direct control exerted by the ice. This control being sufficient to force the streams to flow up hill and over elevations of 100 to 400 feet, we must, apparently, suppose that their courses were determined before the motion of the ice ceased and while it was still thick enough to hold to its normal trend regardless of even quite strongly accentuated topographic features. How the subglacial channel or tunnel originated is not considered, beyond the suggestion that it may be due to the enlargement of longitudinal crevasses; but the point is not vital, for it is obvious that the subglacial water must escape and that, no matter how closely pent, there must always be lines of least resistance to its flow.

At and beyond the margin of the ice, the phenomena must be essentially the same as for superglacial streams; and a frontal barrier or sill of any kind causing the stream to rise, perhaps fountain-like, must favor the aggrading of the floor of the tunnel by the coarser detritus and a corresponding elevation of the roof by corrasion and melting. If the stream is sufficiently long-lived, this process may continue until the deposit attains the level of its terminal alluvial cone or delta. The breadth of the deposit is sharply limited by the stability of the ice arch; and if we should assume two hundred feet as the maximum breadth of ice tunnels, portions of most important eskers would demand some other explanation, and in many cases a breadth of 500 or 1000 feet would prove inadequate. In fact, the subglacialist finds it convenient in such cases to suppose: either that the stream rose through crevasses, perhaps in consequence of the clogging of the tunnel, and became superglacial for a longer or shorter distance; or that the tunnel became, by excessive ablation, locally roofless, or open to the sky, and the resulting canyon was widened by the recession or melting back of the walls. As in the case of superglacial streams, the water is supposed to be diverted after a time, and the deposit left in the abandoned tunnel gradually develops the steep lateral slopes and other formal features of eskers during the slow melting of the retaining walls and arch of ice.

Finally, effective crevassing throughout the zone of esker formation and a failure of englacial drift to rise to any considerable elevation in the ice are always postulated as important, if not absolutely essential, elements of the subglacial hypothesis.

Review of Evidence.

Direction or Trend of Eskers.—That the typical esker tends to conform closely in trend with the movement, and especially with the latest movement, of the ice-sheet, as recorded in the striæ, drumlins and boulder-trains is undoubtedly true. The movement of the ice-sheet must have been, in general, normal to its margin, or, in other words, in the direction of its steepest surface slope, and therefore in the direction which superglacial streams would necessarily follow. Eskers depart from this ideal trend no more than might reasonably be expected, in the case of a superglacial stream, considering that as the ice-sheet becomes thin its surface contours must begin to show the influence of the underlying topography, and considering further the inevitable inequalities in the distribution of the superglacial drift due to and in turn determining unequal ablation, as well as the natural tendency of streams to meander with diminishing gradient. In brief, the trend of the superglacial esker is entirely consistent with the known facts and the reasonable probabilities of the case; and it matters not, so far as this feature is concerned, whether the ice was absolutely stagnant at the time the esker was formed or still retained a part or the whole of its velocity when in its prime.

On the other hand, the only factors which may be considered as directly influencing the direction of subglacial streams and eskers are: the ground topography, which is often contrary or indifferent; crevasses, which, in so far as they exist at all, must be chiefly transverse and therefore indifferent; and the movement of the ice, or the differential pressure of the ice upon the ground resulting from its movement. That the basal movement of a sheet of ice thick enough to flow over a deeply and irregularly corrugated surface of very low average gradient, the gradient being often opposite or transverse to the movement, would tend to develop and maintain furrows or tunnels in the bottom of the ice is extremely doubtful. Tunnels meeting the requirements of esker formation would not

usually lie in the lee of prominent topographic reliefs—ledges or hills, which might, conceivably, have grooved the bottom of the ice as it flowed past them. Nor is it easy to see how tunnels due in any direct way to ice-flow and pressure could have been so indifferent to the topography as eskers are often observed to be, forsaking broad valleys hundreds of feet in depth to continue, perhaps in a very oblique or closely parallel course, across an uneven upland. As previously noted, there must be, as long as the ice is in motion, a tendency to equalize the basal pressures and prevent the development of open spaces by flow of the ice and also by flow, in obedience to the ice pressure, of the underlying drift or ground moraine; and, furthermore, the effects of unequal pressure would be, at least to some degree, neutralized by the differential or localized melting induced by the pressure through the lowering of the melting point. Again, in their longer reaches as well as in their minor meanders, eskers are often obliquely or directly transverse to the last recorded ice movement; and to that extent the movement of the ice must have tended strongly to obliterate or sweep away the deposits of the subglacial streams as fast as they were formed. Stone says,* “The longer meanderings transverse to the direction of ice flow certainly add some difficulties to the hypothesis of subglacial streams.” This difficulty, together with the fact that the formation and maintenance of tunnels transverse to the ice movement is well-nigh inconceivable, and the further fact that eskers and the plains to which they are tributary were clearly formed at a time when the ice was so far wasted as to have a very irregular and fragmentary margin, have led Davis and other adherents of the subglacial theory to hold with the superglacialists that eskers were formed mainly, at least, after the ice became stagnant. But it is obvious that the control of the subglacial drainage demanded by the subglacial theory must originate in the motion of the ice; although, it may, conceivably, survive the cessation of that motion. In other words, the subglacial theory of eskers requires us to suppose that the subglacial streams were established before the ice ceased to move; but that, as a rule, eskers were formed by these streams after the ice became

* *U. S. Geol. Surv., Mon. 34*, p. 426.

stationary. This nice adjustment of conditions made the streams relatively long-lived; and makes it appear the more improbable that they promptly abandoned their courses when the eskers were finished. The meanders of eskers, which are certainly among the most constant and striking features, rather seldom exhibit any definite or causal relation to the topography of the bedrock and till; and, since they cannot be correlated directly with the movement of the ice, the subglacialist can only suggest that they may have been determined by one or more systems of crevasses, of the existence of which there is little or no independent evidence. In view of all these considerations, it is, perhaps, not too much to say that the superglacial theory affords at once the simplest and most natural explanation alike of the general trend of eskers, the major deviations from this trend, and the minor deviations or meanders.

Length of Eskers and Esker Systems.—In the absence of crevasses, superglacial streams are limited in length only by the breadth of the zone of ablation; and superglacial eskers only by the breadth of the zone of englacial drift which has become superglacial by ablation; and the last, in turn, depends upon the height to which the englacial drift has risen in the ice. We have seen: that observations on existing glaciers are practically valueless as evidence of crevassing in the Pleistocene ice-sheet; that the Greenland ice-cap is free from crevasses except near the margins, where it breaks over the restraining mountains; that, if the Pleistocene ice-sheet had been effectively crevassed (that is, from top to bottom) in its passage over the vast peneplain tracts of the glaciated areas, the crevasses would have been gradually obliterated during the extremely slow cessation of the movement, anterior to the period of final ablation of the now stagnant ice-sheet, when eskers were formed; that even on the moraine and forest-covered outer zone of the Malaspina glacier, crevasses are practically wanting, the streams originating within this zone through surface melting being superglacial and so continuing as they flow down the terminal ice slope; and that glacial potholes are by no means conclusive proof of the existence of *moulins* or crevasses in the ice sheet at these points. Add to all these considerations the probability that such crevasses as might possibly appear in the ice-sheet and survive the cessa-

tion of its motion would become clogged and closed by superglacial drift falling and washing into them, and it will be seen that the burden of proof fairly rests upon those who find in the crevasses of the Pleistocene ice-sheet evidence of the non-existence of important superglacial streams.

During the period of growth and maximum development of the ice-sheet the entire volume of the drift must have been englacial: and through the processes of shearing and overriding it must have tended constantly to rise to higher and higher levels in the ice. As opposed to this elevation of the englacial drift we have only the supposed fact that the velocity of the ice increases upward from the bottom, tending to bear down the upward-sloping shear-planes. Observation shows that this is true of alpine glaciers of high surface gradient; and, doubtless, it would be true, in diminishing degree, for the lower gradients of an ice-sheet, if the viscosity of the section were uniform. It is in the highest degree probable, however, that, owing to the outward flow of the terrestrial heat or the rise of the isogeotherms, the temperature of the ice-sheet during and after its prime increased downward, being highest at the bottom. This accords with Nansen's observations on the Greenland ice-cap, previously quoted. Now the mobility of the ice, or its tendency to flow through the differential melting and freezing of its component granules, is a function of the temperature, inasmuch as it must increase with the temperature and reach its maximum at the melting point, which, as previously noted, may be lowered as much as one degree Cent. by the pressure. Here in the lower levels of the ice-sheet, is the true zone of flow, passing gradually upward into the colder zone of fracture, which normally terminates upward in the *névé*, in which the fractures are promptly healed by the freezing of infiltrating water, by settling and by fresh snow fall. These considerations clearly suggest a tendency, at least, to a reversal of the law governing the vertical distribution of velocity; and to the extent or degree of the reversal, the tendency of the upper layers of ice to bear down or depress the obliquely rising englacial drift will be neutralized. It is even conceivable that the distribution of velocity may favor or accelerate the rise of drift; and the writer feels that, in view of these arguments, the transfer of drift in large volume to a consider-

able height in the ice, and over a wide area, may be asserted with renewed confidence. Granted a waning ice-sheet free from crevasses and well supplied with superglacial drift over a broad marginal zone, and the conditions are ripe for the development, through the agency of superglacial streams, of eskers and esker systems equal in length and continuity to any which have been described.

The difficulties of the subglacial hypothesis are here relatively, much more serious, since it requires us to postulate and maintain continuous ice tunnels from five miles or less to one hundred and fifty miles or more in length. In fact, the formation, either before or after the ice has ceased to move, of subglacial streams and tunnels one hundred to one hundred and fifty miles long, extending back to points where the thickness and pressure of the ice must be very great and crevasses are practically impossible, can be accepted only as a last resort, or when the failure of the alternative explanation has been demonstrated.

Varying Width of Eskers. —The expansion of superglacial streams to form lakes of greater or less breadth is normal, and the most extreme variations in the breadth of eskers present absolutely no difficulty; while, as the product of subglacial streams they are simply inexplicable, requiring, according to Stone, tunnels of all widths up to three-fourths of a mile. The broad eskers described by Stone,* in which a medial ridge of coarse gravel is flanked on either side by and merges with a plain of finer gravel and sand, the whole being, often, confined to one side of a valley, by an ice border, and, like true eskers, crossing ridges from one valley to another, indicate, as recognized by Stone, the formation of a normal esker in a narrow channel, followed by a considerable expansion of the channel, permitting the deposition of the finer material of the bordering plain. This broadening of the channel might, in the case of a superglacial stream, be attributed to the melting back of the ice walls, or better to localized surface ablation due possibly to water saturating drift which has accumulated on the ice through previous ablation. So great is the difficulty of explaining these broad deposits by deposition in subglacial chan-

* U. S. Geol. Surv., Mon. 34, pp. 440-444.

nels that Stone,* after a careful study, reaches the conclusion that through the obstruction of the tunnel, perhaps by the sagging of its roof, the subglacial stream rose through crevasses with its burden of coarse gravel and became, for a longer or shorter distance, superglacial. Chamberlin, on the other hand, suggests that an ice tunnel became locally roofless, and then by lateral recession of its walls, the ice canyon became a lake. But it is obvious and generally conceded that superglacial streams afford by far the simplest and easiest explanation of these and all other lateral expansions of eskers, including the not uncommon terminal expansion, where the esker merges with the frontal plain or delta. The only serious questions raised by any one are as to the possibility of persistent superglacial streams with a sufficient volume of formerly englacial drift within their reach; and these difficulties disappear before the conclusions to which we have been forced that effective crevassing was of rare occurrence and high-level englacial drift abundant.

Concerning the more usual widenings of the eskers of Maine, Stone says,† “When within about 75 miles of the coast, every few miles enlargements of the ridges are found which have various forms. Sometimes they are little tables only 200 to 300 feet wide and two or three times as long. These may be solid or may contain one or more shallow kettleholes. Here and there a hummock appears on top of the esker (esker), rising 20 to 40 feet above the rest of the ridge, and at these pinnacles the ridge is generally broader than elsewhere.”

Varying Hight of Eskers.—Woodworth's correlation of variations of hight with variations of original breadth of the esker deposit and of the ice channel in which it was formed, applies in only a limited number of cases. It does not, for instance, account for the broad and flat cols or depressions, or for the occasional high knolls or pinnacles, or for sharp crests of rapidly varying hight. Except where Woodworth's principle does apply, or masses of ice have been buried by the growing esker, or it has suffered erosion, the subglacial hypothesis calls for substantial uniformity of hight, or at least for an even and continuous crest line, as well as for a close

* *U. S. Geol. Surv., Mon. 34*, p. 444-448.

† *U. S. G. S., Mon. 34*, p. 415.

approximation of the crest to the level of the terminal plain, with a gradual rise above that level to the northward if the stream was sufficiently long-lived to permit the complete aggrading of its bed. The superglacial hypothesis, on the other hand, explains coincidence in height with the terminal plain, but requires it only where aggrading has continued during the entire period occupied in letting the esker down upon the ground. When aggradation has ceased earlier than this, the final adaptation of the esker to the uneven surface of the ground may rise to pretty nearly all the observed irregularities of elevation. The high points or knolls are, however, as previously noted, best explained as due to late deposits contributed by hanging lateral valleys; and this harmonizes well with the fact that they occur usually at a bend in the glacial river. The subglacial hypothesis, on the other hand, appears to leave the exceptionally high points unexplained. Height of the esker above its base, or elevation above its terminal plain, are not crucial tests; but the superglacial stream appears, on the whole, more competent than the subglacial stream to account for the observed facts.

Branching of Eskers.—The subglacial streams of a stagnant ice-sheet should branch in essentially the same fashion as the existing or postglacial streams of the same region; and the branches should, in general, be aggraded almost equally with the main stream. But this is clearly not the fashion of eskers, for they are little given to true, river-like branching, especially in their lower or more southern courses; and branches making large angles with the main esker are almost unknown. In fact, there are practically no branches, in the sense of minor tributaries to a main line; but we observe instead an occasional confluence at very oblique angles of eskers of approximately equal size and length, suggesting the primary rather than the secondary or lateral branching of rivers. This, as previously noted, is all precisely what we should expect in the case of superglacial streams on the comparatively high gradient of the marginal slope of the ice-sheet, with so great a thickness of easily-eroded ice above the base level that the main stream had no difficulty, with its higher gradient, in cutting its canyon below the canyon of its lateral tributaries and making of the latter

hanging valleys, in which the aggrading will necessarily be unimportant. Stone says,* in this connection, "From whatever point of view we look, the difficulties are immense in accounting for the branchings of the rivers of the ice-sheet, their directions and their relations to the relief forms of the land, the nature of their sediments, etc., on the theory that we are dealing with subglacial streams alone."

Double and Reticulated Eskers.—That the superglacial deposits afford, in the case where the bordering ice disappears before the underlying ice, a complete and satisfactory explanation of the double eskers has been noted; while as subglacial deposits they are essentially inexplicable, whether the adjacent and parallel tunnels which must be postulated are regarded as contemporaneous or successive in their formation and aggrading. Similarly, the reticulated eskers and kames are most easily explained as superglacial deposits, representing the delta-like branching of the superglacial stream at points where it was approximately base-levelled and the surface of the bordering ice had been reduced nearly to its level by general ablation. Another explanation would be that the deposit formed in a lake-like expansion of the river was split up into a network of ridges through the unequal melting of the subjacent ice, while it was being let down upon the ground. It is an essential part of the superglacial hypothesis that while, through subfluvial and basal melting, the more or less perfectly aggraded deposits may be let down on *terra firma* without being seriously disordered, exceptions must occur of such character and frequency as, apparently, to explain every aberrant phase of esker formation.

Stone shows† that the reticulated eskers, like the broad eskers and esker terraces, are most readily and satisfactorily explained by supposing that the subglacial streams became locally, at least, superglacial. Again, he says‡ that subglacial streams crossing hills and ridges are inconsistent with the existence of crevasses which might divert the water, which "bides its time and at the first eligible transverse crevasse steals off sideways toward the lower ground." Also, that in the

* U. S. G. S., *Mon.* 34, p. 324.

† U. S. G. S., *Mon.* 34, p. 465.

‡ *Ibid.*, p. 299.

discussion which follows the tunnels are assumed and not accounted for.

Topographic Relations of Eskers.—The main points under this head have been duly considered; and it remains simply to note once more that they are, practically without exception, more accordant with the superglacial than the subglacial hypothesis. The very usual haphazard relation of an esker to the contours of the bed-rock and till are seen to be entirely normal for a superglacial deposit; while from the subglacial point of view they are a perpetual enigma. Besides the general indifference of their trends to the modern drainage, which has, perhaps, been sufficiently considered, we have the fact that they are not, as a rule, distinctly contrasted in size or in the coarseness of the gravel on northern and southern slopes. The subglacial stream was comparable with the flow of water in a pipe; and the velocity for any given head was inversely proportional to the diameter of the tunnel, and independent of the local gradient, the velocity being the same on northern or ascending as on southern or descending slopes. But, obviously, the tendency to aggrading of the stream bed is far greater on northern than on southern slopes, in spite of the uniform velocity; and it is also obvious that the esker of subglacial origin should be stronger, more perfectly aggraded, and composed of much coarser material on the up than on the down slopes. This contrast may, perhaps, be noted occasionally, but it is by no means so marked or general as the hypothesis requires.

Eskers belong chiefly to the moderately dissected peneplain tracts and are not especially characteristic of deep mountain valleys where, unquestionably, the conditions were most favorable to crevassing and a concentration of the glacial drainage beneath the ice. Again, the usual lateral position of valley eskers is entirely normal for the superglacial and inexplicable for the subglacial hypothesis. To cite a single instance, in the village of Bridgewater, Nova Scotia, on the southwest side of the La Have river, the valley of which is here some three hundred feet in depth, a well formed esker trends approximately parallel with the valley and at an elevation of about one hundred feet above the river. That a subglacial stream of water could have hung on this steep slope

is well nigh inconceivable, and contrary, as previously noted, to all our observations on existing glacial streams. The fact that, in general, eskers trend toward cols or depressions in water partings calls for no special comment, since it is entirely consistent with both hypotheses.

Relations of Eskers to the Ground Moraine.— Eskers, as well as their terminal plains, normally overlie the ground moraine or till, the only important exception being when, locally, the till is wanting and they are superposed directly upon the underlying bed-rock; and they are rarely, if ever, covered by till, or even sprinkled with bowlders, except such as might readily be supposed to slide or fall into a superglacial channel from the bordering slopes of ice. This relation is, in every particular, strictly normal for superglacial fluvial deposits; but the subglacial fluvial deposits could not possibly escape being covered by till and angular bowlders on the melting of the ice, except on the supposition that the englacial drift was so strictly limited to the basal portion of the ice during the esker-forming period as hardly to warrant its classification as englacial, which would make the maximum elevation of drift in the Pleistocene ice-sheet distinctly less than in the Malaspina glacier and many of the Greenland glaciers. If the normal esker is of subglacial origin, then the englacial drift was indeed scanty and confined to very low levels in the ice, and the subglacial stream was deprived of one important and necessary source of detritus for aggrading its bed and building its terminal plain. The only alternative, apparently, is to suppose that the subglacial stream always held tenaciously to its course until finally, through the general process of ablation, superficial and basal, its tunnel became roofless at all points. This would mean, for one thing, that every esker was formed in part, or at the last, in earth-bottomed canyons open to the sky, which is impossible wherever the grade rises southward, as, practically, it does for nearly every true esker in some part of its course. The subglacial esker must remain under cover, under a roof of ice thick enough to hold the subglacial stream to a channel which, regardless of the ground topography, crossed, directly or obliquely, ridges hundreds of feet in high, until it is finished; and then, as a necessary corollary, the stream which made it must completely abandon its

channel, perhaps scores of miles in length, before the esker is uncovered at any point south of which it rises to a higher elevation. How the subglacial stream is to be diverted while the ice is still several hundred feet thick above it, and how it fails, in general at least, to build an esker in its new channel, are points which have not, perhaps, been duly considered.

Several writers have emphasized, perhaps unduly in some cases, the brevity of the time required for the formation of an extensive sand-plain and its tributary esker, a few years, or even a single season, being considered sufficient in most cases. On the other hand, we are asked to suppose that the subglacial tunnel, often many miles in length, is formed at a time when the ice still has a definite motion, to the controlling influence of which the tunnel is supposed to owe its general trend, that the meanders and transverse reaches of the tunnel are not obliterated by the motion of the ice, and that the tunnel as a whole survives the necessarily slow cessation of the ice movement. This insures to the tunnel and the stream which formed and maintains it, a good degree of longevity and time for the slow building of the esker and terminal plain. But these deposits testify, in composition and structure, to rapid work by torrential streams; and the stationary ice margin during their formation points unequivocally to the same conclusion. It is an interesting question, therefore, as to what the subglacial stream was doing during the relatively long period of its existence anterior to this brief period of tremendous constructive activity; and also as to why it should then abruptly abandon the channel to which it had adhered so long. In brief, the trend of the subglacial stream demands ice control and a long life; its deposits demand a short and intensely active life followed by a sudden disappearance from the scene of its labors. But, whether it be long- or short-lived, its existence should be recorded in the ground moraine, in the form of interbedded gravels before the ice ceased to move, and of erosion channels after the ice became stationary. These phenomena, however, are of rare occurrence, and still more rarely can they be correlated with subglacial streams or eskers. This important problem will receive farther consideration in connection with the source of the material of eskers and sand-plains.



Relations of Eskers to Frontal and Delta Plains.—The main facts under this head are well determined and there is little question or controversy concerning them. My purpose is simply to call attention to the very numerous plains of modified drift, including many true delta plains, which have no tributary eskers and, apparently, never have had. They have, however, undoubtedly been formed through the agency of glacial streams. If these were superglacial streams, the explanation of the absence of associated eskers is simply, as previously noted, that the plain was formed, and the stream diverted before its channel was sufficiently base-levelled to permit any notable aggrading. But if, instead, they were subglacial streams, the aggrading of their beds must have been in progress during their entire existence, or at least during all the time required for the formation of the terminal plain; and the aggrading must, approximately, have kept pace with the upward growth of the plain, else we should not have the good general agreement in height between eskers and plains so commonly observed. That a large majority of superglacial streams should disappear and leave no record, save in the terminal plains, is not surprising; but it is difficult to understand how subglacial streams can do the same. They should certainly be marked, either by aggraded or by eroded channels; for we cannot suppose that eskers were formed and subsequently swept away by currents which left the ice-contact slopes of the sand-plains intact.

Composition and Structure of Eskers.—Little need be added here to what has been noted under the characteristics of eskers. The true significance and evidential value of the main facts have been well expressed by Stone, where he says,* "My conclusion is that where the whole of a ridge of till, from which the finer detritus has plainly been washed by water, has lost all signs of stratification and has a pell-mell structure, the best interpretation is that it was deposited upon the ice in a superficial or englacial channel, and that when the ice underneath the sediment melted, the gravel slid down irregularly and the original stratification was lost. * * * * In general we remark: A stratified internal structure is consistent with either subglacial or superglacial streams. Pell-mell structure of a large mass of glacial gravel strongly favors the hypoth-

* U. S. G. S., Mon. 34, p. 424.

esis that it was deposited on the ice, not beneath it." Add to this confession of a subglacialist the undoubted fact that the structure of the typical esker is essentially pell-mell, or at least chaotic to such a degree that Davis* has hesitated to describe the very normal eskers of the Boston basin as stratified in any true or ordinary sense, and that the occasional appearance of anticlinal stratification must be chiefly, at least, the result of sliding as the gravel gradually adjusts itself to the slowly vanishing walls of ice; and it becomes apparent that no argument fatal, or even inimical, to the superglacial origin of eskers lurks in the coarse, rude, chaotic or anticlinal structure of the latter. Even the openwork gravel on which Davis so confidently relies, appeals to me as finding its readiest explanation, as previously noted, in the loosening up and differential settling of the coarse and irregular detritus during the melting and vertical recession of its icy floor; and I make bold to claim it as specially cogent argument for the superglacial origin of the eskers in which it occurs.

Stone's monograph is the most complete contribution yet made to the natural history of eskers; and no one has discussed the theory of eskers more fully and impartially. In fact, his work is particularly notable for the judicial and fair-minded attitude toward the rival hypotheses which it reveals. Although holding, with Chamberlin, Davis and others, that the subglacial hypothesis affords the best explanation of a certain ideal type, he is disposed, as we have seen, to refer the wide eskers, the branching eskers, the reticulated eskers, the unstratified eskers and perhaps others, to the agency of superglacial streams. These concessions are certainly sufficient to give the superglacial hypothesis a good standing; and the chief objection urged against a still broader application of this hypothesis is the supposed prevalence of crevasses in the marginal zone of the ice-sheet, a supposition which is, in my opinion, essentially groundless.

Source of the Material of Which Eskers and Their Terminal Plains are formed.—The all-important question here is as to whether the material was derived chiefly from the englacial or the subglacial drift; and if from the former, whether it was supplied to superglacial streams through superficial

† *Proc. Bost. Soc. Nat. Hist.*, 25, p.

ablation or to subglacial streams through the erosive action of the stream itself on the roof and sides of its tunnel. Assuming, in view of the preceding discussions, that the englacial drift was sufficiently abundant and extended to a sufficient height in the ice to meet the requirements of esker and plain formation through the agency of superglacial streams, and recalling that all drift set free by superficial ablation is, virtually, within easy reach of the superglacial streams and available for the aggrading of their beds and deltas, we may now give our attention particularly to the subglacial streams.

The subglacial drainage could derive but little detritus from the englacial drift without such an enlargement of the tunnel as would cause its collapse, and it is, therefore, practically limited to the subglacial drift or ground moraine; for crevasses are probably wanting, and even if they were not, to depend upon detritus washed into them from the surface of the ice-sheet would be, as we have already noted, to grant a greater volume and height of englacial drift than subglacialists have heretofore been willing to allow. What opportunity has the subglacial stream to erode the ground moraine. On the first obstruction of its mouth, by standing water or terminal deposit, it must begin to aggrade its bed and erosion here almost or wholly ceases. We have already noted the absence of tributary streams, and if such existed, their beds also, at least in their lower courses, would necessarily be aggraded with that of the main river. On either side of the tunnels the ice rests heavily upon the ground, and the marginal lakes of valley glaciers as well as crevasses filled with water, show that the basal contact must usually be so tight as to permit a movement of water only by seepage, which could, at the best, effect the removal of only the finest or clayey part of the drift. The absence of an adequate available supply of material is, to my mind, the most serious of all the objections to the subglacial theory of eskers. Anyone who considers the great extent and depth of many of our delta plains, and the vast volumes of material required to form them and their tributary eskers, will not doubt that, if derived from the subglacial drift, the latter should show extensive erosion over the areas to the northward; but we look in vain for evidence of such erosion, although its record should be very distinct in the cases where

many millions of cubic yards of sand, gravel and bowlders have been delivered through a single narrow channel, not to mention the still greater volumes of clay and quartz flour which we know must once have been incorporated with the coarser detritus. If the subglacial hypothesis be true, the region to the north of some of our extensive sand-plains ought to have been, in large part, swept bare of till or ground moraine; but we do not find it so; and it could not be so, as long as the ice-sheet rested upon and protected it.

Davis concluded that the Newtonville and Auburndale eskers must be products of subglacial streams acting on subglacial drift, because they contain fragments of slate and conglomerate which must have been derived from the ledges within two to four miles to the northward; and he thinks it improbable that englacial drift could, in so short distance, rise to the level of superglacial streams. The proportion of material from near-by sources is, however, very small, certainly not more than ten and possibly not more than five per cent.; and the elevation of this small fraction of the drift a hundred feet or so in, say, three miles does not impress me as offering any special difficulty. Still farther within the Boston basin, as in the vicinity of Newton Upper Falls and West Roxbury, at distances of from four to eight miles from the granitic northern border of the basin, the proportion of drift of local origin is still very small, the granite rocks from the northern highlands constituting from 90 to 99 per cent. of the whole; while neighboring sections of till show, as usual, that it is mainly of strictly local origin. As I have previously stated, this contrast is what we should expect in any case, since the modified drift has been transported by water as well as by ice; but it is also evidence, if not complete proof, that its glacial transportation was in part englacial. In the eskers to which Davis particularly refers, the detritus of relatively local origin is found near the top as well as near the bottom of the section, though perhaps less abundantly; and *that* detritus is surely even more of a difficulty for the subglacial than for the superglacial hypothesis, since it presupposes that the subglacial stream could erode the bed-rock or till above which it had already aggraded its channel fifty to one hundred feet.

NOTE.—Since this paper was written, I have learned that to Prof. N. H. Winchell properly belongs the credit of first sug-

gesting, as long ago as 1872, that the till or boulder clay was mainly or wholly englacial during the maximum stage of glaciation, that it became largely superglacial during the final ablation of the ice, and that eskers were formed in superglacial channels. I am disposed to regard basal melting also as an important factor in releasing and depositing the ground moraine, and conceive that only thus have drumlins and the true "hard pan" been accumulated. But with this exception, the present argument may be regarded as a defense and elaboration of professor Winchell's views, which, although based primarily upon earlier work done in Ohio, were first published in the Annual Report of the Geological and Natural History Survey of Minnesota for 1872 (p. 62) and in the Proceedings of the American Association for the Advancement of Science for the same year, (pp. 158 and 159), and again in the Popular Science Monthly for March, 1873, and more recently (1884) in Vol. 1 of the Final Report of the Minnesota Survey (pp. 665-669), where the name (esker) of Rice county is described and discussed. To Upham, however, we are still indebted for the vital principle that the ice floor of a superglacial stream may be eroded far below the base level: and it is not too much to say that without this contribution the superglacial argument would be still very inconclusive.

**ON THE DECEPTIVE FOSSILIZATION OF CERTAIN
PELECYPOD SPECIES AND ON THE
GENUS EURYMYA.**

F. W. SARDESON, Minneapolis

The differences in preservation as fossils of molluscan shells of calcite and aragonite are familiar to geologists. The less destructible shells may be the only ones to resist maceration long enough to bury under slowly building sediments and are then alone fossilized; or where all shells have fossilized some are preserved, while the more soluble ones occur only as cast and mold; or further, changes within the rock stratum may have altered or reduced the ones and have obliterated the others. In the case of Pelecypoda of the Paleozoic age, tho all must have had shells and all were capable of fossilization, yet not being equally so, some species may be found and other species may be absent in a given stratum. Also in the many pelecypods which had double layered shells, the one part either the inner or the outer, may remain after the other part of the

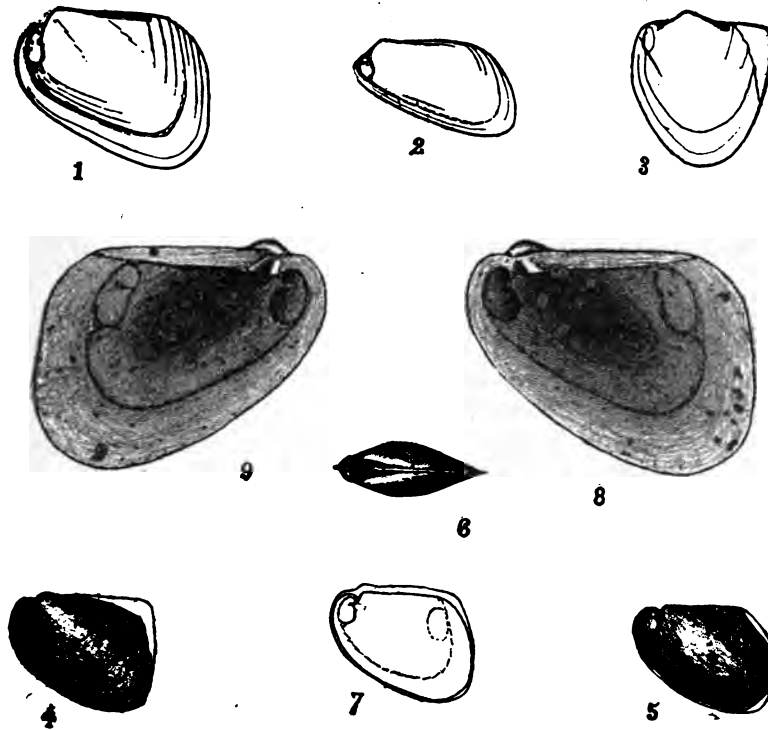
same shell has vanished. Both imperfection of fauna and deceptive fossil structure may accompany the specimens as they are collected.

A special case of this kind, and one worthy of note as an example of a subtle deceptiveness which may exist in a large number of fossils of this kind in the Paleozoic rocks, is presented by the pelecypod, *Modiolopsis plana* Hall, a species from the Galena (Trenton) stage of the Ordovician. It is very deceptive in features arising on account of the shells having dissolved while the sediment was solidifying. The species is further important as the basis for the genus *Eurymya*, into the definition of which the deceptiveness of the fossil has entered. The fossil appears one of the simplest, while in reality it is one of the most complex owing to the manner of fossilization. It appears so well preserved that the biologist would, quite according to custom, write descriptions of the forms to serve as definitions of the species, yet, in fact, such definitions are in this case not correct and a more correct description is here given of the original shell characters after careful reconstruction.

Modiolopsis plana Hall is not a rare fossil and occurs widely in the lower beds of the Galena stage in Wisconsin, Illinois, Iowa and Minnesota, and should be seen in any good collection of fossils of this region. The same manner of preservation prevails in distant localities and has only exceptionally been found to vary. As to the usual preservation, these fossils are black imprints in limestone and represent both external molds and internal casts of the valves. These vary from flat to strongly convex, or respectively concave surfaces upon which as a rule the shell characters are indistinct, as if from a thin shell; but when distinct the muscle scars and varices of growth are superimposed. In a split piece of limestone one may find for example the opposing imprints of a single valve of which the concave mold bears both growth varices and muscle scars and the convex internal cast bears also both muscle scars and growth varices. Placing the two imprints together, no space of measureable width remains, as if the shell had been a mere film in thickness,—a fact which may be overlooked by the collectors unless pains be taken to match the several casts and molds. The imprints were

produced. I think, by thick shells buried or burrowed into sediment, which were dissolved away leaving merely a black stain in place of a shell, while the imperfectly consolidated matrix closed then into space evacuated by the shell. The cast and mold compressed one upon the other and hence each received some imprint of the other. The new black film forms a cleavage plane which the frost, much better than the geologist's hammer, may open.

The composition of the shell of this species was evidently different from that of associated pelecypods since the latter are differently fossilized, occurring abundantly as casts and molds, to be sure, but having open dividing spaces where the shell formerly lay, showing that the shells resisted absorption and held until the sediment around them had set.



Description of Figures of Modiolopsis plana H.

1. A laterally compressed imprint.
2. A vertically compressed specimen.
3. A longitudinally shortened specimen.

4. Artificial cast from a mold of the exterior. The reconstructed portion was broken away before fossilization.
5. Internal natural cast of the same specimen.
6. Dorsal view of the same cast.
7. Outlines of figs. 4 and 5 in normal relation to show the shell thickness on the dorsum.
8. Right valve $\times 2$ reconstructed.
9. Left valve $\times 2$ reconstructed.

Specimens figured are all from the Galena (Trenton) stage, zone no. 2. Figures 1, 2 and 3 are of specimens from Minneapolis, Minn.: fig. 4—7 are from Argyle, Wisconsin.

The consolidation of the sediment would presumably be by vertical compression, as is evidenced in the distortion of *M. plana*; those casts which lie horizontally being flat, (fig. 1.) upright ones being convex (fig. 2.) and rarely one standing on end is then shortened (fig. 3.). Part of this distortion is however due to compression after the matrix was consolidated. There should be distinguished therefore (a) compression during solidification of the matrix, affecting *M. plana* but not other pelecypods, the shells of which were yet extant, and (b) compression since the solidification and after the removal of the shell substance of other molluscs and from this all have suffered distortion more or less, according to locally different conditions.

A specific reconstruction from a series of these fossils to determine both the original form, by estimating the amount of distortion from vertical compression of the matrix, and also the thickness of the shell as evidenced by the sometimes strongly marked anterior muscle scar and pallial line, would seem to indicate that the original shell or its fossil cast if preserved like associated ones, would be very different from that which *M. plana* *H.* was supposed to be. Fortunately specimens have been found which *are* preserved like other pelecypods and although they at first appear to be a different species and even genus they are simply the normal of the same. In one of the shelly rock laminæ filled with casts and molds of all shells at Minneapolis, a cast of *M. plana* *H.* has been detected which seems to have escaped the total compression owing to protection of surrounding shells. At Argyle and Dodgeville, Wisconsin, I have found also several normal molds and casts, one of which is here figured (figs. 4, 5, 6.) and, near these, other specimens which are compressed in

varying degree to that of the common black imprint. Besides the above there occur at Minneapolis, casts of *M. plana* H. in shale strata above the limestones, and these were probably from clay-filled shells, the filling having gained firmness by infiltration of lime from the shell, and the casts are thus often normal. The shells have either disappeared or are represented by a thin covering upon the cast, with intensified concentric varices of growth.

The most favorable form of preservation for study of the species is that of the uncompressed casts and molds in limestone. These show, as expected, characters not heretofore described in the species, especially the hinge plate is different from that which has been supposed to exist.

It seems quite unnecessary to repeat here a detailed description of the shell's outline which is represented by the accompanying figure, but it may be added that the shell varies somewhat in curvature of the ventral margin, a slight sulcus being evident rarely. Also in the posterior extension of the cardinal line, young shells have generally acutely rounded angles, while larger ones may have the same broadly rounded. A broad umbonal ridge extends obliquely backward and above it, the shell is concave, giving a decidedly alate appearance to the postero-cardinal margin. Anterior to the beaks is a similar but small alate flattening. The beaks curve, approaching each other and the cardinal margin. Varices of growth are few to numerous on the surface of the shell.

Internal scars show the pallial line far from the shell margin, especially so in larger specimens. The anterior muscle scar is reniform, deep, and crossed or "divided" by a small ridge, which appears as a depression on the cast. Above the anterior adductor scar is a small, deep protractor scar. The posterior adductor scar is large but not deeply impressed. The shell thickness was 1 to 0.5mm. in an average specimen, and there was a broad strong hinge plate, which beneath the beaks, bore one large broad tooth on each valve with corresponding sockets, the tooth on the left valve being anterior to that of the right valve. Four specimens show this structure, two of them by cast of the edge of the cardinal plate as in fig. 6, and two others by the whole surface, one of each valve. The degree of individual variation can not be determined from so few specimens, but they indicate that a strict interpretation from a single specimen would be erroneous for the species as a whole, since there are various additions to the one tooth, viz. a small posterior tooth on the right valve of one specimen, a small left anterior tooth on another specimen, and a slight tooth or sub-fold upon the contact face of the large teeth in a third.

The species varies in all characters, but not evidently to such a degree that absence of hinge teeth is to be expected

except from accident of fossilization. The original figure by James Hall in *Geol. Wis.*, vol. 1, (1861) p. 38, fig. 6, is evidently drawn from an average specimen of *M. plana* and is well enough represented to make identification of the common specimens not difficult. It shows no hinge teeth. The description and figure by E. O. Ulrich in 19th Ann. Rep. Geol. Sur. Minn., p. 224, is not a fair one and represents an extreme of the alate posterocardinal region. The species as seen in an ordinary collection has not so little variation as he represents in its characters, and in fact his *M. plana H.* is only one extreme of which *M. similis Ulr.* proposed at the same time (op. cit., p. 225) is the other. The differences ascribed to these species are certainly not real and no others have been discovered. *Modiolopsis similis Ulr.* is again described in Final Rep. Geol. Sur. Minn., vol. 3., p. 504. pl. 34, fig. 1 and 2; pl. 42, fig. 19, with the suggestion that it "belongs to the line which finally produced *M. modiolaris*." At the same time a new genus, *Eurymya Ulrich*, is founded on *M. plana Hall* the chief characteristic of which seems to be "an obscene cardinal fold or tooth in the left valve and a corresponding depression in the right," op. cit., p. 512. This character might in fact be seen on any one of the appressed black imprints which are always imperfect, but better specimens show more. *Eurymya* is based on a fossil remnant of true characters of the species. Ulrich's two reconstructed figures (27 and 28, pl. 36, op. cit.) of *M. plana H.* are not alike, being in different degrees imperfect.

The evident fact that a not uncommon, apparently well preserved fossil should be so subtly unlike the shell from which it originated, seems worthy of emphasis. It argues that the 50 or more Ordovician species of the genus *Modiolopsis* as given by S. A. Miller's catalogue, and some other species of similar genera, with few probable exceptions, may have normally had hinge structures similar to that of *M. plana H.* and yet appear as they do, to have been thin edentulous shells; and that even a large collection of a species can not be relied upon to show true structures until the hinge teeth are either known, or their absence on the shell has been carefully determined. Many existing descriptions and figures are not to be accepted without reserve.

The variability of hinge in *M. plana* *H.* is not to be taken as limited to that which is indicated by the few known superior specimens, but the details of it as given correspond well with the great variability of other Ordovician species such as *Vanuxemia rotunda* *Hall* (numerous synonyms) in which no constant number of teeth can be ascribed to the species, although they are few, large and sharply defined, and always appear on the fossil, the variation being as great as here found in *M. plana* *H.* And likewise the presence or absence of hinge teeth may be specific only as further suggested by the few, obtuse teeth of rudimentary appearance on *M. plana* *H.*

What use there may be for the generic name *Eurymya* *Ulr.*, if any, is not decided, but the following considerations are suggested by the evidence here presented. If as much latitude be ascribed to the genus in proportion as there are variable as compared to invariable characters in the type species, then *Eurymya* might readily include or be included in the older named genus, *Matheria* *Billings*. Certainly the genus *Eurymya* as described by Ulrich (aside from any mistake as to hinge structure), has less latitude in characters than that now seen in the type species. *Eurymya* redefined in accord with the characters of *M. plana* as now understood would be included in the definition of his later genus *Modiolodon* (*op. cit.*, p. 521.); "Ovate shells of the same general type as *Modiolopsis* and *Modiomorpha*, but having from one to three oblique cardinal teeth in each valve." This definition seems more adequate for a genus which is to include plastic Ordovician species, and in absence of means for scientific revision of these fossils, there must remain an open question whether this might not better be extended to include also less than one hinge tooth, referring then all these species back to the genus *Modiolopsis* for the present.

HUSSAKITE, A NEW MINERAL, AND ITS RELATION TO XENOTIME

B. H. KRAUS AND J. REITINGER

During the course of extensive researches with the rare earths, which are being conducted by Prof. W. Muthmann of the Technical High School, Munich, there was found to be a dearth of material from which the oxides of erbium and gadolinium can be obtained in larger quantities. The raw yttrium oxide obtainable in commerce, which is doubtless derived from the most part from fergusonite proved to yield a comparatively low percentage of erbium. The same may be said of the products obtained from sipylite, which Dr. K. Th. Postius* has been investigating in Prof. Muthmann's laboratory.

Therefore, the thought suggested itself that perhaps the xenotime from Minas Geraes, Brazil, might lead to better results. In 1886 Gorceix† published a paper on the xenotime from Dattas, near Diamantina, which he said occurred there in considerable quantities and contained a good deal of erbium, but no gadolinium. Through the kind assistance of Dr. E. Hussak of Sao Paulo, it was possible for us to obtain in a very short time a quantity sufficient to conduct a thorough investigation of this interesting material.

The material sent by Dr. Hussak was found by a careful microscopical examination to be homogeneous and not in the least decomposed. Several crystals with well preserved faces were also found, so that crystallographical measurements could be made. These, as will be seen later, agree very closely with those of xenotime inasmuch as only a few analyses of xenotime have been published, a chemical investigation of the clearest and most transparent pieces was at once made. The remarkable fact soon presented itself that a considerable amount of sulphuric acid is present in the mineral. By means of the soda reaction on charcoal a number of crystals were tested for sulphuric acid and without an exception the presence of this acid could be shown. This is very striking, for neither does Gorceix mention the presence of sulphuric acid in this mineral

*DR. K. TH. POSTIUS. Untersuchungen in der Yttergruppe, Inaugural Dissertation, Technical High, Munich, 1902, 1-30.

†Gorceix, *Comptes rend.* 1886, 102, 1024.

nor do any of the analyses of xenotime, which were at our disposal, show its presence.

Chemical Analysis.

The first point to be settled by the quantitative analysis was whether the sulphates form an accessory or an essential constituent of the mineral. The latter was found to be the case. The following statement concerning the method of the quantitative chemical analysis may prove to be of interest to mineralogists.

The mineral is a sulpho-phosphate, and aside from these two acids, contains only the earths of the yttrium group. Fe_2O_3 was found to be present in very small quantities, while Al_2O_3 , CaO , and MgO could not be determined. The decomposition was effected by means of the alkali carbonates. The operation takes place quite easily. The material usually requires to be heated for half an hour before the blast-lamp. The fused mass was first treated with water. The earth carbonates are insoluble; but on the other hand, all the sulphuric acid and most of the phosphoric acid are dissolved. In this aqueous solution the amount of the two acids could then be determined. The portion, insoluble in water, may be treated in two ways. First, it may be dissolved in nitric acid and the small quantity of phosphoric acid precipitated by means of molybdenum solution. After the removal of the molybdenum solution and the precipitation of Fe_2O_3 and Al_2O_3 with sodium acetate, the earths may be rendered insoluble by the addition of ammonia. Or, second, it may be dissolved in hydrochloric acid, and after precipitation of the earths as oxalates, the phosphoric acid, Fe_2O_3 , and Al_2O_3 may be determined as usual. By means of continued heating before the blast-lamp, the earths were converted into the oxides. After treating them with sulphuric acid, the equivalent weight was determined in the usual way. In this manner the atomic weight of the mixture of rare earths was found to be, in this case, 103.25. The cathode-luminescence method* was used to spectroscopically show the presence of a small percentage of Gd_2O_3 together with considerable Y_2O_3 . The Er_2O_3 , contained in the mixture of earths, was determined spectroscopic-

*Muthmann und Baur, Ber. d. d. chem. Ges. 33, 1748.

ally by comparison with a solution of chemically pure Er_2O_3 of known strength. Knowing the amount of Er_2O_3 present, and also the equivalent weight of the mixture of the earths, it was a very easy matter to determine the amounts of Y_2O_3 and Gd_2O_3 .

Spectroscopically we had found 24.6% Er_2O_3 in the mixture of the earths.

Now if,

x = percentage of Y_2O_3 and

y = percentage of Gd_2O_3 , then

we have,

$$x + y + 24.6 = 100.$$

$$\text{Also } \frac{x}{226} + \frac{y}{360} + \frac{24.6}{380} = \frac{100}{254.5}.$$

From which we obtain

$$x = 72.1\% \text{Y}_2\text{O}_3,$$

$$y = 3.3\% \text{Gd}_2\text{O}_3.$$

It may be further mentioned that the mixture of the earths was very carefully tested for cerium and didymium, and that even the most sensitive reactions failed to show a trace of these elements. Lanthanum is certainly not present for the spectrum, obtained by the method already mentioned, did not show any brilliant lines characteristic of oxide. The results of the quantitative analysis are as follows:

I.	II.	III.	
$\text{SO}_3 = 6.13\%$	not det.	6.13%	
$\text{P}_2\text{O}_5 = 33.50$	33.52%	33.51	$\left\{ \begin{array}{l} \text{Y}_2\text{O}_3 \\ \text{Er}_2\text{O}_3 \\ \text{Gd}_2\text{O}_3 \end{array} \right.$
$\text{R}_2\text{O}_3 = 60.21$	60.28	60.24	
Fe_2O_3 not det.	0.20	0.20	
		100.08%	

I, first analysis; II, second analysis; III, average of I. and II.

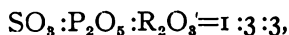
The earths are present as follows:

$$\text{R}_2\text{O}_3 = 60.24 = \left\{ \begin{array}{l} \text{Y}_2\text{O}_3 = 43.43\% \\ \text{Er}_2\text{O}_3 = 14.82 \\ \text{Gd}_2\text{O}_3 = 1.99 \end{array} \right.$$

Taking 254.5 as the molecular weight of R_2O_3 , the following molecular ratios result for $\text{SO}_3 : \text{P}_2\text{O}_5 : \text{R}_2\text{O}_3$.

I.	II.	III.
$\text{SO}_3 = 0.0765$	not det.	0.0765
$\text{P}_2\text{O}_5 = 0.2359$	0.2360	0.2360
$\text{R}_2\text{O}_3 = 0.2365$	0.2369	0.2367

These figures agree with considerable accuracy with the proportion:

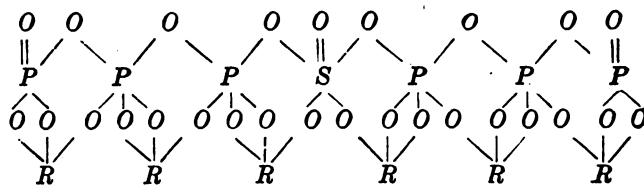


and hence the empirical formula may be considered as:



The analysis showed that the mineral in question is no simple orthophosphate, hence not xenotime, but a considerable amount of sulphuric acid, as already mentioned, is also present. The amount of sulphuric acid present is constant, as was clearly shown by several other determinations, which in every case agreed very closely with the figures given above. Therefore, this is evidently a new mineral, which we wish to name hussakite in honor of Dr. E. Hussak of Sao Paulo, who assisted greatly in our investigations by obtaining this very interesting material for us.

A graphic formula for hussakite may be easily constructed from the empirical formula, if we assume two atoms of phosphorus present as constituents of pyrophosphoric acid and the remaining four as orthophosphoric acid. In this manner the following symmetrical formula is obtained in which R represents the mixture of Y_2O_3 , Er_2O_3 , and Gd_2O_3 :



Crystallographic-optical Examination.

The material, which was used for the analysis, contained a number of clear, transparent crystals, the edges of which were not in the least rounded. The faces were all well preserved. The crystals were about 2 to 3 mm. in length, 1 to 2 mm. thick, and of a dark brown color. Most of the faces gave very good images so that the measurements could be made with considerable accuracy.

The crystals are of a prismatic habitus and generally show the simple combination of (110) with (111). On all the crystals, which were measured, the faces of (110) were generally of the same size. The pyramid (331) was also observed on sev-

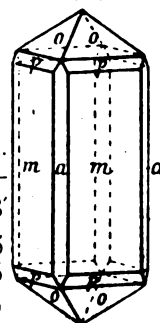
eral crystals. This form is always quite small. On one large crystal, the edges of which were very much rounded, the prism of the second order (100) could be easily detected. The faces of this form were quite large, but measurements could not be made with any degree of accuracy. A number of well preserved crystals showed a twisting and contortion, which are so characteristic of quartz. This same phenomenon was observed by W. E. Hidden* on xenotime from McDowell Co., N. C. Figure I shows a combination of all the observed forms, namely: *m* (110), *a* (100), *o* (111), and *p* (331). In all nine crystals were measured.

The results are as follows:

Crystal system: Ditetragonal bipyramidal.

Axial ratio: $a : c = 1 : 0.6208$.

	Observed.	Calculated.
(111) : ($\bar{1}\bar{1}\bar{1}$)	$= 82^{\circ} 34'$	—
(111) : (111)	55 34	$55^{\circ} 38'$
(331) : ($\bar{3}\bar{3}\bar{1}$)	138 24	138 25
(331) : ($\bar{3}\bar{3}\bar{1}$)	82 51	82 46
(100) : (110)	45 10	45 0



The axial ratio as well as the various angles agree very closely with those of xenotime. Dana† gives $1 : 0.61867$ as the axial ratio for xenotime, while Groth‡ accepts $1 : 0.6177$. The axial ratio of hussakite agrees much better with the ratio given by E. Hussak¶ for xenotime from the same locality, namely, Dattas. His figures are $1 : 0.62103$, the difference being two units in the fourth decimal place. Likewise, the angles agree remarkably well with those observed by H. Gorceix° on crystals, which he described as xenotime.

The following table shows the great similarity between several of the angles of hussakite and xenotime.

	Hussakite	Xenotime		
	Kraus:	Dana:	Hussak:	Gorceix:
(111) : ($\bar{1}\bar{1}\bar{1}$)	$= 82^{\circ} 34'$	$82^{\circ} 22'$	$82^{\circ} 15'$	$82^{\circ} 30'$
(111) : (111)	$= 55 34$	$55 30$	$55 22$	$55 34$

As already mentioned, the crystals are generally transparent, especially when quite thin. When thick, translucent.

*American Journal of Science, Nov., 1898, 36, 380-383.

†Dana, System of Mineralogy, 1892, 748.

‡Groth, Tabellarische Uebersicht der Mineralien, 1898, 84.

¶E. Hussak, Tschermak's Mittheilungen, 1891, 12, 457.

°H. Gorceix, Compt. rend. 1886, 102, 1024.

The crystals, which were measured, possess vitreous lustre; those more or less rounded have a greasy or pearly lustre. The color is yellowish white, honey yellow, brown, or dark brown.

Hardness=5.

The specific gravity, determined by means of the hydrostatic balance, was found to be 4.587 at 20° C.

Perfect cleavage parallel to *m* (110).

Fracture uneven; streak white to yellowish white.

In a thin section, perpendicular to the *c* axis, hussakite shows in convergent polarized light a normal uniaxial interference figure. The character of the double refraction is positive.

From a transparent crystal about 1 cm. long and 0.5 cm. thick Voigt and Hochgesang of Göttingen ground a prism with the refracting edge parallel to the *c* axis. This prism was used to determine the indices of refraction for lithium, sodium, and thallium lights. The method employed was that of minimum deviation. The results are as follows:

	w	e	e-w
Lithium light	1.7166	1.8113	0.0947
Sodium "	1.7207	1.8155	0.0948
Thallium "	1.7244	1.8196	0.0952

The images produced by the sodium and lithium lights were very sharp and hence these observations are reliable. The image of the ordinary ray for thallium light was not as well defined as for the other colors but this determination may, nevertheless, be considered as fairly accurate. The image of the extraordinary ray for this same color was very much blurred and hence two separate determinations were made, namely, 1.8183 and 1.8209, which differ considerably from one another. The value given above is the mean of these two observations.

If we consider the determination for lithium and sodium lights as reliable and then calculate the indices of refraction for thallium light by means of Cauchy's formula

$$n = A + \frac{B}{\lambda^2},$$

we obtain

$$w = 1.7245 \qquad e = 1.8194$$

as the theoretical values for this color, which agree quite closely with the observations given above.

The values *e-w* show that hussakite has a very strong double refraction and consequently the fine powder gives very vivid interference colors in polarized light.

Relation of Hussakite to Xenotime.

From the foregoing, it is evident that several points yet remain to be explained, which we now wish to discuss briefly.

The different results obtained by Gorceix and ourselves are very striking, for the material analyzed by Gorceix is from the same locality from which our crystals were obtained. According to Gorceix, the mineral examined by him is without a doubt identical with that which we possess. For the sake of comparison we wish to give both analyses side by side.

	Gorceix:	Reitinger:
P ₂ O ₅	35.64	33.51
R ₂ O ₃	63.75	60.24
Fe ₂ O ₃	—	0.20
Insol.	0.40	—
SO ₃	—	6.13
	99.79	100.08

The 6.13% sulphuric acid found by us is evidently divided in Gorceix's analysis between P₂O₅ and R₂O₃. We cannot, with any degree of certainty, account for this difference; we infer, however, that Gorceix simply overlooked the sulphuric acid and decomposed his material with either concentrated sulphuric acid or potassium bisulphate and thus had no occasion to determine the sulphuric acid, which he had no reason to suppose present. Nevertheless, we would like to emphasize the fact that all undecomposed hussakite crystals from Dattas have the composition given by us above.

Why is it that the crystal form of hussakite is identical with that of xenotime. In general, we are accustomed, when two substances have the same crystal form, to consider them as identical. This question has a simple solution when we consider that all analyses of xenotime, aside from those of Gorceix and one by Blomstrand,* were made with more or less decomposed material. It seems plausible to consider that, which is called xenotime, as nothing else than a hussakite from

**Zeitsch. f. Krystal.* etc., 16, 68. Blomstrand indicates that the mineral was decomposed with sulphuric acid and hence it was impossible for him to determine whether sulphuric acid was present in the mineral or not.

which the sulphuric acid has been extracted by the circulating waters in nature and thus converted into an orthophosphate.

In order to determine whether or not this might be the case, we treated finely pulverized hussakite with a solution of sodium carbonate for a short time on the water bath. It was clearly shown that the sulphuric acid can, in this manner, be easily removed from the mineral; for after an hour's heating, the filtrate gave a very distinct reaction for sulphuric acid. No doubt the circulating waters in nature, which generally give a weak alkaline reaction, may have acted on hussakite in a similar manner and in due time changed it to an orthophosphate.

If this supposition be correct, it would be reasonable to assume that the opaque xenotime crystals are pseudomorphs of yttrium orthophosphate after hussakite, and that the partially decomposed crystals must show a presence of sulphuric acid.

In a sand from Banderia de Mello (Bahia) opaque crystals of a pyramidal habitus were found, which Dr. E. Hussak* determined and described as xenotime. Through the kindness of Dr. Hussak a larger quantity of this sand, which aside from xenotime also contains corundum, quartz, garnet, monazite, and other minerals, was placed at our disposal. The crystals of xenotime were carefully isolated and examined chemically. On crushing them it was found that they were opaque and partly decomposed. The quantitative analysis gave a distinct reaction for sulphuric acid. The results of the quantitative analysis of this "xenotime" from Bandeira de Mello are as follows: †

	I.	II.	
P ₂ O ₅	27.40	27.35	
SO ₃	2.62	2.74	
SiO ₂	0.65	0.59	
R ₂ O ₃	60.03	59.87	} Y ₂ O ₃ Er ₂ O ₃ Gd ₂ O ₃
Fe ₂ O ₃	4.58	4.50	
Al ₂ O ₃	1.10	1.22	
CaO	2.51	2.60	
MgO	0.49	0.41	
H ₂ O	0.34	0.40	
	99.72	99.68	

*E. Hussak, *Tschermak's Mitteilungen*, 1891, 12, 457.

†Recently Dr. J. REITINGER (*Analytische Untersuchungen über die natürlichen Phosphate*, etc., Munich, 1902.) made another analysis of finer specimens from this same sand and found only 1.14 per cent SO₃.

The molecular weight of the mixture of rare earths, R_2O_3 , determined by the method indicated above, was found to be, 249.7. The earths are present in the following percentages:

	I.	II.
Y_2O_3	45.93	45.80
Er_2O_3	13.68	13.65
Gd_2O_3	0.42	0.42
	<u>60.03</u>	<u>59.87</u>

Of course it is just as impossible to obtain a rational formula from this analysis as from Blomstrand's* very careful analyses made with material from Hvalö and Narestö near Arendal.

The small percentage of sulphuric acid found in this material from Bandeira de Mello makes it very interesting for it is evident that this is a transition product between hussakite and xenotime in which only a portion of the sulphuric acid has been extracted by the circulating waters in nature. During this decomposition, other substances as indicated in the analysis above, have been deposited in the cracks and pores of the mineral. The crystals of this so called xenotime are of a pyramidal habitus, very much rounded and worn and hence the faces are dull so that very accurate measurements could not be made; but nevertheless, it was shown that the angles of these crystals agree very closely with those given above for hussakite. Inasmuch as the crystals were opaque it was impossible to examine them optically.

Hence, there seems to be no doubt but that those xenotime crystals, which are opaque and free from sulphuric acid, as used for most analyses, are pseudomorphs after transparent hussakite.

As further evidence in proof of this theory, we wish to state that we are able to show the presence of sulphuric acid in several crystals from Htterö,† which are in the possession of the Bavarian Mineralogical Museum in Munich, and which Prof. P. Groth kindly placed at our disposal. These crystals were partially decomposed, hence in some places opaque, while

*Blomstrand, *Geolog. Förr. Förrh.*, 1887, 9, 185, also *Zeitsch. f. Krystall.* 15, 99.

†Until now, only one analysis has been made from the xenotime from this locality, namely, that by Schiötz. The large percentage of water present shows that the material was decomposed and hence all the sulphuric acid had doubtlessly been extracted in the manner cited above.

in others they seemed quite fresh and undecomposed. Two such crystals were examined for sulphuric acid and in both instances it was found to be present. These reactions were even more distinct than those obtained with the material from *Bandeira de Mello*. The material placed at our disposal was insufficient for a complete quantitative analysis. Several other Norwegian xenotimes, which are also in the Mineralogical Museum at Munich, were examined but they did not contain sulphuric acid. These specimens were from *Arendal*, *Rade*, near *Moss*, and *Htterö*, and were very much decomposed and absolutely opaque, having doubtlessly been formed from hussakite, as mentioned above. Hence, we believe that from what has been said in the foregoing, we are justified in stating that if yttrium orthophosphate be called xenotime, then xenotime, in so far as it occurs in crystals, is to be considered as a pseudomorph after hussakite.

Since the publication of this paper in German,* Dr. H. Rösler† has shown that hussakite occurs quite frequently as an accessory constituent of granites and quartz porphyries, as also of the kaolinites resulting therefrom. Rösler also observed several crystals of hussakite, which show a distinct pleochroism; w = pale rose to yellow brown, e = brownish yellow to gray brown; absorption $e > w$.

NOTE ON THE SO-CALLED BASAL GRANITE OF THE YUKON VALLEY

R. G. McCONNELL, Ottawa

Distribution and general description.

Granite gneisses closely resembling the Laurentian gneisses of eastern Canada are widely distributed along the upper part of the Yukon valley. They have been traced by various members of the Canadian and U. S. Surveys from the Nordenskiöld river in a northwesterly direction across the White river valley to the Tanana and down this stream to near the mouth of Delta river, a total distance of about 380 miles. The north western boundary crosses the Yukon from the south a

**Zeitschr. f. Krystall*, 34, 268-277

†*Neues Jahrbuch für Mineralogie, Geologie, etc.*, 1902, B. B. XV, 231-393.

‡Published by permission of the Director of the Geological Survey of Canada.

few miles below the mouth of Pelly river, and recrosses it above the mouth of Fortymile river. Between these two points areas of granite gneiss and other igneous schists are of constant occurrence. The gneisses are also found on the lower fifty miles of the Stewart river a northeastern tributary of the Yukon and on the lower part of White river, a stream entering the Yukon from the opposite direction a few miles above the mouth of the Stewart. The width of the gneissic belt on the Stewart and White rivers, the only point at which it is even approximately known, measures 110 miles.

The area roughly defined above, 380 miles in length and 110 miles in width, is only partially underlain by gneisses. In the region examined by the writer, the gneisses alternate with bands and areas of altered clastics consisting mostly of dark and lead gray quartz-mica schists, hard quartzites and crystalline limestones, and they are overlain by wide areas of comparatively recent sedimentary and pyroclastic rocks, associated with andesytes, rhyolites and basalts, all of which have been referred provisionally to the Tertiary.

The gneisses, as might be expected considering their wide areal distribution, exhibit great variety in texture, composition and general appearance in the field. The ordinary variety is a grey medium textured, granular rock, passing on the one hand into a fine grained schist, difficult and occasionally impossible to distinguish from the recrystallized clastics with which it is often associated, and on the other hand into an exceedingly coarse grained and unmistakable gneissoid granite. Porphyritic phases are also not uncommon. A wide band of reddish augen gneiss crosses the head of Australia creek, the feldspar crystals of which are drawn out into lenses often two inches in length. Areas and bands of augen gneiss, often alternating with the ordinary granular variety, were also noticed at several points in the Yukon valley and on the Stewart. Near Selwyn river the gneisses have a striped or banded character due to the alternation of light grey and dark varieties in bands of irregular width. The dark bands differ from the light colored ones only in containing a larger proportion of the dark ferromagnesian minerals. The banding in all cases appeared to be parallel to the schistosity.

Mineralogy.

The principal constituents of the gneisses are quartz, orthoclase, oligoclase and albite in varying proportions, and biotite. Hornblende is often present as well as biotite and in places the rock passes into a diorite schist. The common secondary minerals are epidote which is almost universally present, garnet abundant only in some localities and chlorite, muscovite and sericite. Bands of green, finely foliated chlorite schist, green and dark hornblende schist, and light grey silvery sericite and muscovite schists, occur both alternating with or fringing the gneisses, and in separate areas. These rocks in some places are so intimately connected with the gneisses, both structurally and mineralogically, that the inference is unavoidable that they simply represent different phases of a common magma, and this may be true in regard to them generally. The principal rock in the vicinity of Dawson is a light grey sericite schist. This rock as a rule is well foliated, and is often entirely recrystallized, but in places enough of the original structure remains to show that it is derived in part at least, from a granite or quartz porphyry.* Similar rocks occur interbanded with the gneisses on Henderson creek, and at other places, and bordering them in the Fortymile district. These rocks have many characters in common with the gneisses, and while they may not in all cases be exactly contemporaneous, they evidently belonged to the same period of igneous activity, and for this reason have been included with them pending further study.

Structure.

The schistosity of the gneisses is far from uniform, the same area often including fine grained well foliated micaschists partially or wholly recrystallized, ordinary gneisses, and coarse gneissoid granites showing little deformation. In some of the larger areas the schistosity becomes more marked towards the boundaries than at the center, but this feature appears to be exceptional. The dips of the foliation are low as a rule, seldom exceeding 45° and probably averaging less than 30° . High dips and sharp flexures do occur but are usually easily accounted for by local causes. On the Stewart river the gneisses have been thrown, at their eastern boundary, into

*A microscopical examination of this rock was made by Dr. A. E. Barlow and his conclusions in regard to its origin agree with the field evidence.

a succession of short sharp folds of extreme complexity. The gneisses at this point are bordered on the east by a large area of massive granite, and the disturbance doubtless took place during its intrusion. The sharp folding continues for a short distance west of the granite, beyond which the gneisses gradually resume their normal attitude. Similar local disturbances due usually to granitic or other intrusions occur also at several points in the Yukon valley and elsewhere, but are always limited in extent, and taken altogether affect only a small proportion of the total gneissic area.

The gneisses in some of the larger areas have been thrown into wide regular folds, in others the dip is constant in the same direction, the clastic schists underlying them at one boundary and overlying them at the other. This occurs both in the case of narrow dyke-like occurrences and wide areas several miles across.

The strikes of the gneisses in the Yukon valley and adjacent region are generally northwesterly. Northeasterly strikes were observed in a few places but are exceptional, and occasionally the planes of schistosity follow curved courses. The strike of the gneisses is often conformable to that of the clastic schists but not universally so.

Jointage planes are conspicuous in the more massive varieties of the gneiss, but are so exceedingly irregular both in strike and dip that it was found impossible to make out any relationship between them. The joints cut the schistosity at all angles, and no distinct sets showing even approximate parallelism in strike were determined.

Previous Views.

The gneisses briefly described above were examined by Dr. Willard Hayes in 1891 in the course of a hurried reconnaissance from the Yukon to Copper river, and referred by him although with some hesitation to the Archean.* In 1896 the occurrences in the Fortymile district were examined in some detail by Mr. J. E. Spurr. Mr. Spurr after discussing the time relationship of the gneisses to the other rocks in the district states that† "It may therefore be concluded that the Fortymile granite is older than the schistose sedimentaries

*Expedition through the Yukon District, *Nat. Geog. Mag.*, Vol. IV.

†Eighteenth Annual Report, U. S. Geo. Survey, Part III, Page 137.

and underlies them." In a preceding paragraph, however, the same writer states "The possibility still exists therefore that the granite may be intrusive, having broken through the sedimentary rocks in a massive body and dragged up the beds so that they lie on its flanks dipping away in all directions." Mr. Spurr in the body of his report refers constantly to the gneisses as the basal granite, but the reasons given for this conclusion are largely theoretical and it is evident from the passage quoted that he did not consider the question absolutely settled. In 1898 the lower White river and the Tanana were examined by Mr. A. H. Brooks. The valleys of both these streams afford good sections of apparently the same gneisses or sheared granites found on the Yukon. Mr. Brooks states that* "definite proof of the basal nature of this gneissoid series is still wanting. There is however strong evidence that the metamorphosed clastic series which lie adjacent to the gneisses are younger, and that the gneisses should be regarded as basal."

Relationship of Gneisses to Altered Clastics.

During the past season the writer examined the Yukon valley from Fort Selkirk to Fortymile, and also spent some time in the Fortymile and Sixtymile districts. The evidence obtained in this investigation all went to prove that the contact between the gneisses and the altered clastics is an eruptive one, and that the latter, so far as known, represents the basement formation of the district. The evidence consisted principally in the alteration and deformation of the clastic schists near the contact with the gneisses or sheared granites, the inclusion of fragments of the clastic schists in the gneisses and the occurrence of thin sheets of gneiss alternating with the schists usually close to the borders of the larger areas.

In the Yukon valley and adjacent region the gneisses as stated previously alternate with the clastic schists in bands and areas ranging from a few feet to twenty miles or more in width. The contacts between the two formations is usually concealed, but in a few places the relationship is clearly shown. A good example occurs on Fortymile river below the mouth of Brown creek. At this point the river cuts across

**Twentieth Annual Report, U. S. Geo. Survey, Part VII, Page 465.*

an area of sheared granite or diorite about half a mile in width. At the junction of the gneiss with the clastic schists, the river is bordered by a high scarped bank affording an excellent section. The gneisses in this area contain more hornblende than is usually the case and in places pass into a diorite. They are coarse grained in the central part of the mass, but towards the boundaries the texture becomes finer and the foliation increases in intensity. The gneisses overlie the clastic schists resting on them at an angle of about thirty degrees and at the junction the schistosity of the former and the bedding planes of the latter are approximately parallel. Narrow dyke-like sheets of sheared granite alternate with the clastics for some distance east of the main area. Near the junction of the two formations the silicious beds in the clastic series have been altered into a hard flinty easily fractured rock, and the more argillaceous varieties into glossy mica schists. The dips at the contact are comparatively regular, but a short distance away the clastic beds have been thrown into almost vertical attitudes and in places are violently contorted. The relationship of the gneiss to the altered clastics suggests faulting in some respects, but this explanation fails to account for the presence of the gneissic dykes, and besides no evidence of extensive faulting has so far been found in the district.

A section from Fortymile river south to Sixtymile river, east of the international boundary crosses two bands of sheared granite alternating with altered clastics. The most northerly of these has a width of less than a mile and in strike and dip conforms to the enclosing clastics, both formations striking approximately east and west and dipping steadily to the north. The second area has a width where crossed by the trail of about six miles but narrows rapidly to the east and in a few miles is cut off by andesytes. The rocks in this band consist of the ordinary grey biotite gneisses along the northern boundary and southward across the strike for two miles, beyond which point they pass into or are replaced by light colored well foliated sericite schists derived from an acid granite or quartz porphyry. The exact contact at the northern boundary between the gneissic granite and the clastic schists is concealed by debris, the nearest outcrops of the

two formations being fifty feet apart. The principal contact phenomena observed consisted of a tilting of the beds to nearly vertical attitudes, the partial brecciation of the clastic rocks, and the shattering of the included siliceous beds. The latter have been altered into hard brittle rocks seamed with a network of irregular interlacing fine lines consisting of quartz and calcite. At the southern boundary the igneous and clastic schists alternate for some distance, the latter dipping under the former at angles of from 10 to 30 degrees. The clastic beds are highly altered but are rendered easy of identification by the presence of included crystalline limestones.

Evidences of eruptive contact somewhat similar to the above and more or less marked were noticed at several points in the Yukon valley section, but it will be unnecessary to describe them in detail here.

Further proof of the invasion of the clastic schists by the gneissic granites is afforded by the frequent inclusions of the former in the latter. In the lower part of the Sixtymile valley and in the Yukon valley for some miles above the mouth of this stream, the gneisses enclose irregular shaped fragments, short bands, and large masses of the clastic schists. The inclusions range from a few feet to half a mile or more in width, and here consist in great measure of white coarsely crystalline limestones, the argillaceous and siliceous beds usually associated with them having been mostly destroyed. The boundaries between the limestones and the enclosing gneisses are usually sharply defined, but in one or two places an apparently gradual transition was noticed from pure crystalline limestone to typical gneiss. Inclusions of quartzites and altered argillaceous rocks occur also in the gneisses a few miles below the mouth of Selwyn river and of the same rocks accompanied by crystalline limestone on Henderson creek and in the Yukon valley above Fortymile river. The inclusions are usually highly altered and when unaccompanied by limestone it is often impossible to separate them with certainty in the field, from some of the fine grained varieties of the gneissic granite.

The dyke like sheets of sheared granite interbanded with the clastic schists, referred to previously as bordering some of the larger areas, can hardly be explained otherwise than

as intrusive along the bedding planes of older rocks. They occur not only in the vicinity of the larger areas but also at considerable distances from them. A dyke of augen gneiss four feet in width sheared parallel to the bedding planes of the enclosing clastics, occurs in the Yukon valley nearly opposite the mouth of Ensley creek, and wider bands are of common occurrence throughout the district. The mineralogy of the narrow gneissic bands so far as worked out is essentially similar to that of the larger areas, the shearing is the same, they traverse the same rocks, and differ from them mainly in the accident of size.

It is evident in view of the facts given above that a part of the gneisses at least must be regarded as intrusive through and therefore younger than the clastic schists associated with them. It is still possible however as the work done so far has been largely of an exploratory character that older gneisses may be present in the district, but no evidence of this was obtained in the course of the investigation.

EDITORIAL COMMENT.

"THE MONTHLY AMERICAN JOURNAL OF GEOLOGY AND NATURAL SCIENCE."

Seventy-one years ago an English gentleman who was known as a geologist, and who had settled permanently near Schenectady, N. Y., started a scientific journal at Philadelphia which had the above title. As a geologist Mr. G. W. Featherstonhaugh was later for a short time engaged with the engineer corps of the United States.* He returned to England and died in France where he was in the diplomatic service of the English government.

The journal which he established was short lived. Twelve numbers, making one volume were issued. It had the competition of the American Journal of Science at New Haven, then known as *Silliman's Journal*, and the personal peculiarities of the editor seem not to have been such as to make the journal unanimously acceptable to the few American geologists and other scientists to whom such a journal ought to appeal.

After considerable search the writer has succeeded in obtaining a complete set of the twelve numbers issued. The volume contains 576 pages, octavo. The first number dates July, 1831, and the last, June, 1832. The subscription price was \$3.50, invariably in advance. It was published by Henry H. Porter, at the office of the *Journal of Health, Journal of Law etc.*, Literary Rooms, 121 Chestnut street, Philadelphia. The journal was well arranged and immaculately proof-read.

Its pages are full of highly interesting scientific matter. In the first number, besides the prospectus, and introduction, by the editor, is a description, with plate, of *Rhinoceros alleghaniensis*, in form of a letter to Dr. Buckland, Oxford, England, by G. W. Featherstonhaugh. The same author presents also a discussion of the "ancient drainage of North America and the origin of the cataract of Niagara," with a "flat view of the cataract," made "upon scale," by George Catlin. This was executed prior to the New York geological survey. It gives measurements in all directions across the gorge, from Goat island to Table rock, curvature of horse shoe fall, etc., etc., and shows the "rapids on the cherty beds of ye Carboniferous limestone." Mr. R. Harlan gives the "diary of a naturalist," kept by John B. Carr "at the Bartram Botanic Garden on the right bank of the river Schuylkill, below the city of Philadelphia," during the spring of 1830. This begins Mar. 1, and ends June 7. It notes the weather and the coming of birds and flowers. The editor's discussion of "Nomenclature," in a short article, is very piquant and amusing, setting forth the striking penchant of the French to consider themselves as having the *langue universelle*, and to convert all scientific terms, even all ideas of classification, into a French cast. There is then an interesting history of the origination of the Wollaston medal and the bestowal of the first of those medals on Wiliam Smith, the father of English stratigraphic geology, 18 Feb. 1831; then an account of the earl of Bridgewater's bequest. A correspondent treats of the "influence of climate on the fruitfulness of plants." The volume closes with a few pages of "scientific memoranda," notes and comment, including a report by a committee consisting of Messrs. Cooper, Smith and Dekay, on a collection of bones from the Big Bone lick, of Kentucky, lately brought to New York city.

In several numbers are lists of the subscribers' names. In the first number this list includes 25 subscribers at Washington and 35 at Philadelphia, the former beginning with "Andrew Jackson, President of the United States (2 copies.)" In the September No. (1831) the list at Washington rose to 29 and that at Philadelphia to 102.

The publisher failed in business, made an assignment, and no accounting for subscriptions paid could be had. This greatly delayed and deranged the journal. Mr. Feathers-tonhaugh continued the journal at his own expense, completing the volume. Every number was filled with interesting and important scientific papers, including several letters from Audubon, then traveling and collecting in Florida.

This publication, which is almost unknown in American scientific literature, contains numerous original geological documents, and constitutes a very creditable beginning of American geological journalism; and it is also a very interesting and valuable historic unit in the development of American science.

N. H. W.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Summary Report of the Geological Survey Department for the calendar year 1901. Ottawa, 1902; pp. 269, and 13 sketch maps.

ROBERT BELL, acting director.

Besides the comprehensive report of Dr. Bell, this document embraces the reports of numerous assistants, all of them general summaries of their work of 1901. There are thirty-one parties in the field, some of them being under the direction of temporary employés generally college professors, who could devote only the summer season to the survey. The various sub-reports are given in the words of their authors and under their own names, instead of being run together under the name of the director. The order of presentation is geographic, running from the northwest to the southeast.

Mr. R. G. McConnell reports on the Yukon district; Dr. R. A. Daly on the western part of the international boundary; Mr. R. W. Brock on the Boundary Creek district of British Columbia; Mr. W. W. Leach on the Crow's Nest coal fields; on Red Deer river, Alberta, and on *Trionyx foveatus* Leidy, and *Trionyx vagans* Cope, from the Cretaceous rocks of Alberta, by L. M. Lambe; on the region southwest of Lac Seul, by Wm. McInnes; on the country west of Nipigon lake and river, by A. W. G. Wilson; on the country east of Nipigon lake

and river by W. A. Parks; on the west side of James bay by D. B. Dowling; on the western part of the Abitibi region by W. J. Wilson; on the eastern part of the Abitibi region by J. F. E. Johnson; the Sudbury district by A. E. Barlow; on the Haliburton and Bancroft areas by Frank D. Adams; on botany and zoology by John Macoun; on borings for natural gas, petroleum and water, also notes on the surface geology of part of Ontario, by Robert Chalmers; on the district around Kingston, Ontario by R. W. Ells; on the petrography of Shefford and Brome mountains by J. A. Dresser; on a geological exploration of Anticosti, by Prof. Laflamme; on New Brunswick by L. W. Bailey; on the coal problem in New Brunswick by H. S. Poole; on Prince Edward Island by L. W. Watson; on Kings and Hants counties, Nova Scotia, by Hugh Fletcher; on the Nova Scotia gold fields, by E. R. Faribault; on the Cambrian rocks and fossils of Cape Breton, by G. F. Matthew; on chemistry and mineralogy by G. C. Hoffman; on the progress of mining in Canada, by E. D. Ingall; on mapping and engraving, by C. O. Senecal; on Paleontology, and zoology, by J. F. Whiteaves; on artesian wells, paleontology, archeology, bibliographies, etc., by H. M. Ami; on entomology, by James Fletcher; and on the Library, by John Thorburn.

This report indicates great activity in the Canadian Geological Survey. Several important memoirs are in preparation, by Canadian geologists which, when published, promise to be valuable contributions to Canadian geology

N. H. W.

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CORRESPONDENCE.

COLUMBIA UNIVERSITY SUMMER SCHOOL. The eastern branch of the Columbia University summer school in geology was held this year at Hudson, N. Y. from June 2 to 9. It has always been the endeavor

of this branch of the school to select a field which combines good stratigraphical, palaeontological and structural features. It was conducted last year by Mr. G. Van Ingen at Rondout, N. Y., where these features were excellently combined. This year Becraft mountain, near Hudson, N. Y., was selected. The mountain was in charge of Prof. J. F. Kemp and Prof. A. W. ... by Mr. H. W. Shimer. The mountain is about ... and four to five hundred feet high ... of the so-called Hudson ... was a continuous deposit ... and including the Lorraine ... sometimes forming the vertical cliff ... zone.

Los Angeles, and is said to be an excellent representation of Dr. Claypole.

MR. J. E. SPURR of the U. S. Geological Survey, who has been for more than a year engaged in work in European and Asiatic Turkey as consulting mining expert to the Sultan, arrived in America June 1. While retaining his European connection, he will this summer undertake special mining work for the U. S. Geologic Survey. He will examine the Grand Encampment copper district in Wyoming, assisted by Mr. F. B. Weeks of the Geological Survey.

GEOLOGICAL EXCURSION AT PITTSBURG. The late meeting of the Geological Society at Pittsburg was marked by a series of local excursions; or, a continuous excursion, about Pittsburg, made under the guidance of Dr. I. C. White, intended to furnish students of the Carboniferous an opportunity to see the great Pittsburg coal and its associated formations in a region where these have been well explored and described by official and other reports. These excursions extended over a week and preceded the date of the meeting. Other shorter excursions were had during the week of the meeting.

IN THE REORGANIZATION OF THE NEW MEXICO SCHOOL OF MINES, several additional professorships will be established, the present courses of study extended, and a number of short lecture courses by specialists introduced. A new building for the metallurgical laboratory has already been begun; the chemical laboratory has been remodelled. Plans are being drawn for an administration building and museum. Besides the mining courses offered exceptional opportunities will be given for advanced geological investigation, especially along the lines of genesis and geology of deposits. For the latter a special chair is contemplated. In addition to the regular appropriations of the legislature the school will now have the income of a three-tenths of a mill tax. The sale of school lands is rapidly increasing the permanent support fund.

PORTLAND CEMENT. In America, the first Portland cement works were started at Coplay, Lehigh county, Pa., by the late D. O. Saylor. This plant, now the Coplay Cement Co., is still in operation, and its cement, "Saylor's Brand," ranks with the best cements of the world. Natural rock cement has been made in America at Rosendale, Ulster county, N. Y., since 1828, at Louisville, Ky., since 1829, and at various other points in New York, Kentucky, Ohio, Michigan, and Maryland, and the hydraulic properties of the cements made from the limestones of the Lehigh Valley were known, but Saylor's plant at Coplay was the first to make the genuine Portland cement. Other plants to follow the one at Coplay, in America, were the Empire Portland Cement Co., of Warners, N. Y.; the Buckeye, near Bellefontaine, Ohio, and the Western, at Yankton, S. D.—
R. K. Meade, in Mines and Minerals.



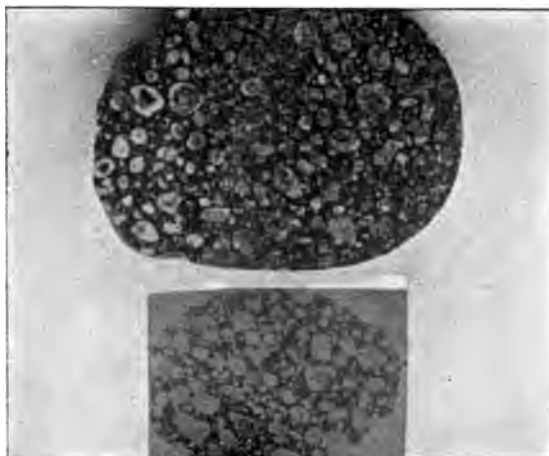


FIG. 1.

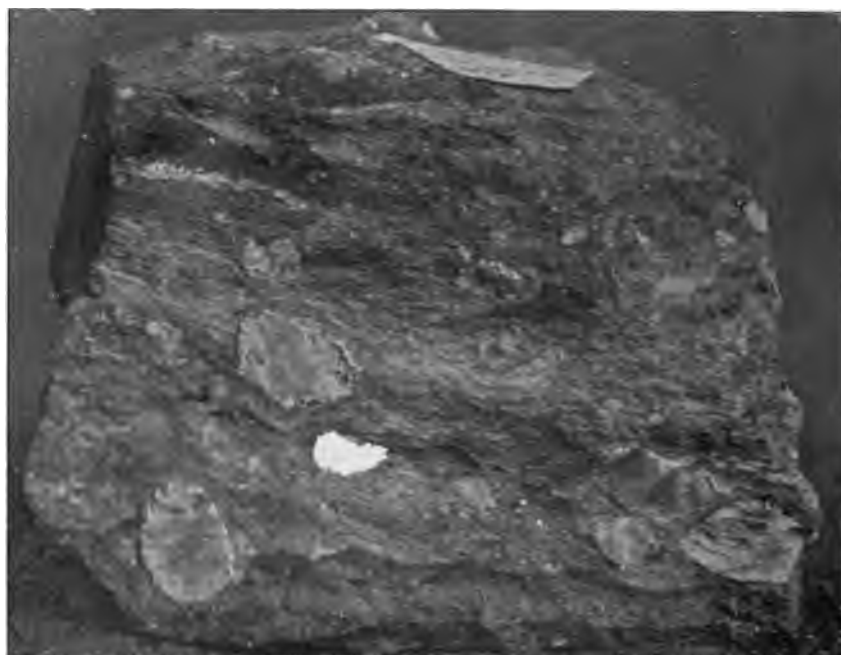


FIG. 2. METAMORPHISM WITHOUT CRUSHING.

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TWO CASES OF METAMORPHOSIS WITHOUT
CRUSHING

B. K. EMERSON, Amherst, Mass.

PLATE I.

I. AN AMYGDALOIDAL AMPHYBOLYTE FROM THE CONNECTICUT
VALLEY

It is still a very difficult matter to distinguish amphibolytes derived from basic eruptive rocks from those derived from calcareous and ferruginous sedimentary rocks. I was therefore much interested in a pebble of a black amygdaloidal amphibolyte which was recently brought to me from Mt. Holyoke. It seems to have come from the large bed of magnetite-amphibolyte in Whately,* a slide of which is figured on plate VI, fig. 1, of the "Monograph of the Three River counties" and classed there with the amphibolytes probably derived† from limestone. This specimen, as shown in figure 1, is certainly an amygdaloid and the shapes of the rounded white spots are unmistakably those of steam holes. The lower figure is a photograph of natural size of a polished surface cut through the middle of the pebble. The upper figure is the photograph of a slide cut 1 mm. above the lower one.

The mass of the rock is however not a dark green and fine grained amphibolyte and is wholly changed from its original condition into a matted mass of fine actinolite needles, some almost colorless and showing only low pleochroism. A few of them larger than the rest project freely into the cavities with perfect terminations, and the ends are often colorless.

*This is 15 miles up the Connecticut valley, in the direction from which the ice came.

†Mon. XXIX. U. S. Geol. Survey, 1898.

Groups of magnetite octahedra are quite common; but there is no trace of leucoxene or epidote. Biotite occurs rarely in red-brown plates.

Green chlorite scales are mingled with the actinolite scales abundantly.

It will be noticed that the centers of many of the amygdules are dark colored. This is from the accumulation there of many larger plates of chlorite and needles of actinolite.

The feldspar is untwinned, perfectly fresh and so free from cleavage that it is difficult of determination by optical methods. In plates showing the central emergence of a positive axis the extinction was 14 degrees indicating albite, but the cleavage against which the measurement was made was indistinct; other measurement indicated oligoclase-albite. It is sparingly interspersed among the other constituents, but fills the cavities sometimes in a granular form that simulates a very fine sandstone. More commonly it occurs in broad interlobate fields that show a perfect granophyric structure: vermiform and clavate lobes of the one penetrate the other adjacent grains or fill them with many isolated grains and rocks.

This mixture of granophyric plagioclase with chlorite and actinolite seems to have been introduced into the cavities by heated solutions in much the same way that the similar limpid and granular albite mixture was introduced into the steam holes in the Triassic traps at Cheapside.*

This original filling of the amygdules may be thought to have persisted while the volcanic rock was altered to a fine grained mass of pale hornblende so entirely simple and regular in texture that it gives no hint of its original character.

The large slide shows not the slightest trace of crushing and the perfect metamorphosis has been effected without any indication of dynamic influences.

It and the Whately rock, with which I have compared it, are of much finer grain than any other amphibolytes of the region. The hornblendes are of the same size, distribution and optical properties. The magnetite is of the same distribution and shapes and the white granular feldspar mosaic is the same in the ground mass of both. The amygdules and their peculiar filling are wanting in the Whately rock, and the

*See fig. 1, plate vii, in *Diabase Pitchstone and mud enclosures of the Triassic Trap of New England. Bul. Geol. Soc. Am.*, vol. viii, p. 76, 84, 1897.

latter has been made slaty by pressure; and it seems to be a result of this pressure that a considerable quantity of fine granular titanite has developed at the expense of the magnetite.

It is remarkable how little breaking up of the long needles has attended the production of the slaty cleavage in this Whately rock.

II. A PORPHYRITIC MICA SCHIST WITH POSSIBLE RIPPLE MARKS.

The block represented by figure 2 was broken from a large boulder in a deep valley east of the road 3 miles south-east of South Monson. It is typical of the Brimfield schist of the region. It has a chocolate shade from the abundant biotite. It is porphyritic with many large grains of feldspar which simulate pebbles perfectly. Each individual is a single cleavage piece nearly an inch long of a limpid moonstone. It is the adularia which from early times has been cited from Brimfield. It is a microcline of exceedingly fine grain, and seems by quite high power to be an ideal untwinned orthoclase. Each individual has a perfect egg or ellipsoidal shape as if it had been turned in a lathe out of a large crystal. At the lower right-hand corner are two such pebble-like forms and directly above is a still more perfect one showing two broad cleavage surfaces but so limpid that it shows dark and inconspicuous in the picture. The one in the lower right-hand corner has grown directly across the bedding and distorted it. The banding is wrapped and wrinkled around them and the "pebbles" are slightly drawn out in points.

There is a delicate and thin layer of finely granulated feldspar surrounding each of the "pebbles" and derived possibly from their incipient crushing. A half inch layer at the bottom of the block is seen to be of a darker color than the rest. It was originally more rusty and is now more biotitic. The upper surface had distinctly the undulating surface of ripple-marking which has been interrupted by the later growth of the large feldspar grain.

Although these later feldspars have grown in the mass and biotite has developed abundantly I think it probable that this is really a ripple-marking.

The way these rounded crystals of microcline have grown in place in the sandstone as it was becoming a schist is not

very clear. They have grown in the rock like a potato in a hill expelling the material of the enclosing rock from the place they have come to occupy. They are unstrained and so have grown under a minimum of pressure. The rocks are strongly folded, and in and by the process of folding the given bed may be in part relieved from pressure and the remaining pressure made equal from all directions. We can imitate this with a thick pile of paper. If it be folded with both ends held firmly there will often be places where the leaves will warp apart from each other. And if something like this were effected where there was a sandy layer between two more rigid layers, portions of the sandy layer might have the pressure thus equalized. And by this equalized pressure the crystal was allowed to grow equally in all directions but prevented from forming crystal faces.

It is curious that the entire metamorphosis of the amphibolyte and the filling of the amygdules each with a central group of coarse hornblende needles in a granular plagioclase should take place without changing the place of the amygdules in the slightest and that the mica-schist should be formed and permit the growth of the large adularias without pressure and without changing the lamination of the rock, and perhaps without disturbing what seems to be a distinct ripple-marking.

THE NEW MADRID EARTHQUAKE

[Compiled from various sources]

By GARLAND C. BROADHEAD, Columbia, Mo.

At the time of the Charleston earthquake in 1886 the country was thickly settled for 500 miles in every direction and the land and its manifestations were closely observed and intelligently recorded.

The New Madrid earthquake of 1811 and 1812 occurred at a time when there were few settlements near, and but few persons made records of the phenomena. But it was felt as far south as Vicksburgh, Miss., and Louisville, Ky., and at other distant places.

Lorenzo Dow, the celebrated evangelist, visited New Madrid in 1815, and observed the effects of the earthquake. At his request Eliza Bryan, of New Madrid, wrote to him on

March 22d, 1816.* This letter was published in newspapers and also in several books. We extract as follows:

On 16th Dec., 1811, about 2 A. M. we were visited by an earthquake shock accompanied with an awful noise resembling loud and distant thunder, but more hoarse and vibrating, followed in a few minutes by complete saturation of the atmosphere with sulphurous vapor and accompanied with total darkness. The affrighted inhabitants ran to and fro. The fowls and beasts cried; trees fell; the Mississippi roared, the current for a few minutes was retrograde. From that time until sunrise there were a number of lighter shocks, then there occurred a much more violent shock than the first, but with similar accompaniments to the first. But the excitement and terror of all animated nature seemed to be double.

The inhabitants fled in every direction to the country. One woman fainted from terror and could not be restored. There were several lighter shocks during the day and some every day until the 23rd of January, 1812, when a shock was felt that was as violent as the most severe of the former shocks. It was accompanied by similar phenomena. From this time until Feb. 4 the earth seemed to be in continual agitation. On the 4th of February there occurred a shock nearly as severe as the preceding ones. On the next day there were four such and on the 7th at 4 P. M. a concussion took place which was so much more violent than the preceding that it was known as the hard shock. The awful darkness of the atmosphere which now, as formerly, was saturated with sulphurous vapor, and the violence of the tempestuous thundering noise that accompanied it, together with the other phenomena mentioned as attendant on the former ones, formed a scene, the description of which would require the most sublime and fanciful imagination. At first the Mississippi seemed to recede from its banks, its waters gathered up like mountains, leaving boats high upon the sands. The waters then moved inward with a front wall 15 to 20 feet perpendicular and tore the boats from their moorings and carried them up a creek closely packed for a quarter of a mile. The river fell as rapidly as it had risen, and receded within its banks with such violence that it took with it the grove of cottonwood trees which hedged its borders. They were broken off with such regularity that in some instances persons who had not witnessed the fact could with difficulty be persuaded that it was not the work of art. A great many fish were left upon the banks. The river was literally covered with the wrecks of boats. There were at that time many boats in the river and at the landing, bound for New Orleans. During all the hard shocks the earth seemed horribly torn to pieces. The surface of hundreds of acres was from time to time covered over for various depths by sand which issued from the numerous fissures. Some of these fissures closed up immediately after they had vomited forth sand and water. What seemed to be coal was thrown up with the sand in some places. It was impossible to say how deep the fissures were. The site of the

*Lorenzo Dow's Works, Cincinnati, 1850, p. 344.

town evidently settled down fifteen feet, but a half mile below the town there does not seem to be any alteration in the river bank, but a little way back, the numerous large ponds which covered a large part of the country were nearly dried up. The beds of some of them were elevated above their former banks several feet, producing an alteration of ten to twenty feet from the horizontal surface. A lake on the opposite side of the Mississippi has been formed over 100 miles long, six miles wide and ten to fifty feet deep.

Since 1811 slight shocks are occasionally felt. It is seldom more than a week but one is felt and sometimes two or three in a day. During the past winter two occurred which were more severe than any felt for two years before, but others were but slight. Formerly severe thunder was often heard, but for more than twelve months before the earthquake there was none felt, and but little since, and much of it resembled subterranean thunder.

Dow says that the vibration of the earth shook down trees, and thousands of willows were swept off like pipe stems, about waist high; the swamps became high ground, and high land became low ground and two islands in the river were so shaken that they were washed away and disappeared.

Prof. J. W. Foster in his *Physical Geography of the Mississippi valley* furnishes us with much interesting information concerning the New Madrid earthquake, as follows:

The series of shocks began near the close of 1811 and continued until 1813. The telluric activity of which these events were a part extended over half the hemisphere and was manifested in a series of stupendous phenomena such as the elevation of Sabrina, one of the Azores, to the height of 320 feet above the sea. The city of Caraccas with its 12,000 inhabitants was destroyed, an eruption of a volcano of St. Vincent, and fearful noises on the Llanois of Calabazo.

New Madrid seems to have been one of the foci of disturbance, and shocks were repeated almost every hour for months in succession. Mr. A. N. Dillard, of New Madrid, gave Mr. Foster much information. The weather had been warm and pleasant, the air was hazy like Indian summer. About midnight, while the French population were engaged in dancing the first shock came, and houses and fences were shaken down. The greatest consternation prevailed, and the people rushed out and Protestant and Catholic knelt side by side and offered up solemn supplications. The shocks were stated to continue for 20 to 30 months. In every instance the motion was from the west or southwest. Fissures would be formed 600 to 700 feet long and 20 to 30 feet wide through which water and sand spouted 40 feet high. There issued no burning flames but flashes such as would result from an explosion of gas, or from passing of electricity from cloud to cloud. Oak trees would be split in the center and for 40 feet up the trunk, one part standing on one side of a fissure, the other part on the other. Mr. Dillard says that his grandfather had received a boat-load of castings

from Pittsburgh and had them stored in his cellar. During one of the shocks, the ground opened under the house and they were swallowed up and never afterwards seen. Near the St. Francis river there is a great deal of sunk land, caused by the earthquake of 1811. Here are large trees submerged ten or twenty feet beneath the water. Previous to the earthquake keelboats would come up the St. Francis river and pass into the Mississippi three miles below New Madrid. The bayou is now dry land. From one of the fissures there was ejected the cranium of an extinct species of ox. In Reelfoot lake the fisherman floats his canoe above the branching submerged tops of cypress trees. Reelfoot lake in Obion Co., Tennessee, nearly 20 miles long and seven broad owes its origin to the sinking of the ground during this period.

Timothy Flint who at one time resided at St. Charles, Mo., and published in 1826 a book of "Recollections" was in this region about 1820 and furnishes a very graphic account of the earthquake phenomena.

Flint says that a tract near Little Prairie became covered with water three or four feet deep and when the water disappeared, there remained a stratum of sand. Lakes twenty miles in extent were formed in the course of an hour while others were drained. The grave-yard of New Madrid was precipitated into the stream and most of the houses thrown down. The whole country between the mouth of the Ohio and the St. Francis including a front of 300 miles was convulsed to such a degree as to create lakes and islands and to cover a tract of many miles extent near Little Prairie with water three or four feet deep; and when the water disappeared a stratum of sand remained. Birds lost all power to fly and retreated to the neighborhood of man. A few persons sank in the chasms but were extricated. Trees were cut so as to fall across the chasms and on these the people would rest. Many persons perished with their boats upon the river. There were many shocks but two series of concussions were particularly terrible. There were two classes of shocks: those in which the motion was horizontal, and those in which it was perpendicular. The latter were attended with explosions and the terrible mixture of noises that preceded and accompanied the earthquakes in a louder degree, but were by no means so desolating and destructive as the other. In the interval of earthquakes, there was one evening—and that a brilliant and cloudless one—in which the western sky was a continual glare of vivid flashes of lightning and of repeated peals of subterranean thunder, seeming to proceed, as the flashes did, from below the horizon. This is said to be the same night on which the earthquake was so severe at Caraccas, and these flashes and that event were part of the same scene.

Switzler's History of Missouri and Campbell's Gazetteer, both contain full information derived from Godfrey Le Sieur, an old inhabitant of New Madrid county.

He says that the first shock came at 2 A. M., Dec. 16, 1811, and was so severe that big houses and chimneys were shaken down and at half

hour intervals light shocks were felt until 7 A. M., when a rumbling like distant thunder was heard and in about an instant the earth began to totter and shake so that persons could neither stand nor walk. Then the earth was observed to roll in waves a few feet high with visible depressions between. By and by these swells burst, throwing up large volumes of water, sand and coal. Some was partly coated with what seemed to be sulphur. When the swells burst, fissures were left running in a northern and southern direction and parallel for miles. Le Sieur has seen them five miles long, four and a half feet deep and ten feet wide. The rumbling appeared to come from the west and travel east. Similar shocks were heard at intervals until January 7, 1812, when another shock came as severe as the first. Then all except two families left, leaving behind them all their property, which proved to be a total loss as adventurers came and carried off their goods on flat boats to Natchez and New Orleans, as well as all their stock which they could not slaughter. On Feb. 17 there occurred another severe shock, having the same effect as the others and forming fissures and lakes. As the fissures varied in size, the water, coal and sand were thrown out to different heights of from 5 to 10 feet. Besides long and narrow fissures, there were others of an oval or circular form making long and deep basins some 100 yards wide and deep enough to retain water in dry seasons. The damaged and upturned country embraced an area of 150 miles in circumference including the old town of Little Prairie now called Caruthersville, as the center. A large extent on each side of Whitewater, called Little River, also both sides of the St. Francis in Missouri and Arkansas. Reelfoot lake in Tennessee, sank 10 feet. In the morning at the time of the second earthquake when water, sand, etc., were being thrown up Le Sieur suggested to his young brother and another young man that they cross the water and, if possible, reach a large Indian mound three miles distant. They went, Le Sieur leading, sometimes swimming, sometimes wading, and throwing logs or bush to make temporary bridges across the deep fissures. After going a mile, a woman was seen calling for help. It was Mrs. Cooper and four children endeavoring to reach the house of Le Sieur's father. They were then seated upon a large fallen sycamore. Le Sieur was unable to reach her, but kept on forward, swimming and wading until they reached higher ground on Red Bank bayou. The water kept rising and they climbed up a grape vine and perched upon a croch of it. After remaining a half hour the water receded. They then returned home where they found Mrs. Cooper safe. They had gone in all directions. The water thrown up during the eruption was luke warm.

Mr. Culberson and family lived upon a farm on the bank of the Pemiscot river where the stream made a sharp bend like the letter V. His house stood opposite the point of the river with about an acre of ground between it and the river. On this ground was a well and his smoke house. On the morning of Dec. 16, 1811, and just after the second hard

shake, Mrs. C. started to go to the well for water and to the smoke house for meat for breakfast, but behold neither could be found. Upon examination they were seen across the river on the opposite side from where they were the evening previous. Gen. Rozier, in his history of the settlement of the Mississippi valley, refers to Godfrey LeSieur's account, also quotes from Henry Howe of the *Great West*. He speaks of the trees waving, the sinking ground and the lightning flashings, rendering all very horrible.

After the severest shocks a dense black cloud of vapor overshadowed the land. The sulphur gases escaping through the cracks, the air became tainted and the water for 150 miles was so impregnated as to render it unfit to use.

Long in his Expedition to the Rocky Mountains speaks of the country between 50 degrees and 45 degrees north latitude limited by the Azores, the Alleghenies, the Green mountains of Vermont, the valley of the Missouri, the Cordilleras of New Grenada, the coast of Venezuela, the volcanoes of the smaller West Indies, all shaken at the same time. The destruction of Caraccas was simultaneous with the earth's agitation at New Madrid, on the Ohio and along the upper Missouri, where it occasioned superstitious dread among the Indians. They thought that the whites had angered the great "Waconda" and he in his wrath caused the earth to shake. Earthquake shocks were felt from May, 1811, until April, 1812, in the island of St. Vincent of the West Indies.

In 1820, eight years after the severe earthquake, passengers from a steamboat went ashore at New Madrid and while examining a collection of books, they felt the house shake and they became frightened. "Don't be alarmed," said the lady of the house, "it is nothing but an earthquake." These concussions were occasionally felt from Red river to the falls of the Ohio. While major Long was at Cape Girardeau on the 9th of November, 1820, a shock was felt sufficient to cause considerable motion of furniture.

Annals of the West, published in St. Louis 1851, has a full account of the earthquake phenomena, chiefly derived from Dr. Hildreth, Dr. Lewis F. Linn in Wetmore's Gazetteer of Missouri, and from Drake's pictures of Cincinnati.

Little Prairie seemed the center, but vibrations were felt all over the Mississippi valley as far up as Pittsburgh. An engineer on a flat boat 40 miles below New Madrid with a load of produce says that in the night while his boat was lying along shore a shock was felt and the men hurried on deck thinking that the Indians had made an attack. After daylight, as they were preparing to depart, a loud roaring was heard sounding like steam escaping from a boiler. This was accompanied by a violent agitation of the shores and tremendous boiling up of the waters in huge swells and tossing the boats so violently that the men with difficulty could keep upon their feet. The sandbars and points of islands gave way, swallowed up in the tumultuous bosom of the river, carrying down with them the cottonwood trees cracking and crashing, tossing their arms to and fro, as if sensible of their danger, while they disappeared beneath the flood. The river which the day before was comparatively clear, being low, now changed to a reddish hue and became thick with mud thrown from the bottom, while the surface, lashed violently by the agitation of the earth beneath, was covered with foam, which gathering in masses the size of a barrel, floated along on the trembling surface. The earth on the shores opened in wide fissures closing again, and water and sand and mud in huge jets were thrown higher than the tree tops. The atmosphere was filled with a thick vapor or gas to which the light imparted a purple tinge resembling but different from Indian summer or smoke. From the check given to the current by the heaving bottom the river rose in a few minutes five or six feet and again rushed forward with redoubled impetuosity hurrying along the boats, now let loose by the horror stricken boatmen, as in less danger on the water than on the land. Many boats were overwhelmed in this manner and their crews perished with them. It required the utmost exertion to keep the boats in the middle of the river. Many boats were wrecked and old snags thrown up from where they had rested for ages. A man belonging to one of the boats remained for several hours on the upright trunk of an old snag in the middle of the river against which his boat was wrecked, but was finally rescued. The sulphurous gases discharged during the shocks tainted the air, and the river water for 150 miles below could not be used for a number of days. New Madrid which stood 15 to 20 feet above the summer flood sank so below that the next rise covered it 5 feet. The neighboring lakes became dry land and have since been planted in corn. The stone and brick buildings at Cape Girardeau were cracked. Near St. Louis fowls fell from the trees as if dead; crockery fell from shelves.

John Bradbury, the English explorer, was on a keel boat passing down the river. On the night of the 15th his boat was moored to a small island near Little Prairie. He observed the shock about two o'clock. In half an hour another shock came. This made a chasm in the island 4 feet wide and 80 yards long. Mr. Bradbury observed that the sound seemed to precede the earthquake at least a second and that it always

proceeded from the same point, and went off in an opposite direction. He also found that the shock came from a little northward of east, and proceeded to the westward. By daylight he had counted 27 shocks.

Hon. Lewis F. Linn, U. S. Senate, in a letter to the chairman of the committee on commerce Feb. 1, 1836, gives a sketch of this part of Missouri. He says:

The memorable earthquake of December, 1811, after shaking the valley of the Mississippi to its center, vibrated along the courses of the rivers and valleys, and passing the primitive mountain barriers, died away along the shores of the Atlantic. In this, during the continuance of so appalling a phenomenon, which commenced by distant rumbling sounds, succeeded by discharges, as if a thousand pieces of artillery were suddenly exploded, the earth rocked to and fro, vast chasms opened, from which issued columns of water, sand and coal, accompanied by hissing sounds, with ever and anon flashes of electricity, rendering the darkness doubly terrible.

Dr. Linn's letter is published in Wetmore's *Gazetteer of Missouri*, 1837, and in the *Western Journal and Civilian*.

Wetmore, in his *Gazetteer*, gives an interesting account, but it includes much that had been published by others. He states that a woman of Little Prairie bore her little children from her house to the prostrate trunk of a tree on which she placed them. She returned to her house for provisions and ordered her husband to take a paddle and steer the log while she held the children.

In a number of the *St. Louis Globe Democrat* of March, 1902, may be found an interesting article from the papers of the late Aug. Warner on the disappearance of Island No. 94. This island was in the Lower Mississippi, not far from Vicksburgh. It seemed that Captain Sarpy of St. Louis, with his family and considerable money aboard, tied up at this island on the evening of the 15th of December, 1811. In looking around they found that a party of river pirates occupied part of the island and were expecting Sarpy with the intention of robbing him. As soon as Sarpy found that out he quietly dropped lower down the river. In the night the earthquake came and next morning when the accompanying haziness disappeared, the island could no longer be seen; it had been utterly destroyed as well as its pirate inhabitants.

In Beck's *Gazetteer of Illinois and Missouri* (Albany, 1823) we find a letter from L. Binégler which had been published in the *American Journal of Science*, Vol. 3, 1821.

The account states that the shock was felt for 200 miles around. There seemed to be a blowing out of the earth, bringing up coal, wood, sand, etc., accompanied with a roaring and whistling produced by the impetuosity of the air escaping from its confinement, seemed to increase the horrid disorder of trees being blown up, cracked and split and falling by thousands at a time. The surface settled and a black liquid rose to the belly of the horses who stood motionless, struck with panic. Afterwards the whole surface remained covered with holes which resembled so many craters of volcanoes surrounded with a ring of carbonized wood, and sand which rose for about seven feet. A few months after, these were sounded and found to exceed 20 feet in depth. The country here was level and covered with occasional small prairies. Now it is covered with ponds and sand hills or monticules which are found where the earth was formerly lowest. There seemed to be a tendency to carbonization in all vegetation soaking in the ponds, produced by these eruptions. A lake was produced 27 miles west of the Mississippi with trees standing in the water 30 feet deep.

Dr. Drake in his "Pictures of Cincinnati," classified the shocks. The first shock of the 16th of December, 1811, that of 23rd of January, 1812, and the first on the 7th of February, constitute the first class. The second class includes those of 7h. 20m. A. M., December 16th, that of 27th January and the 10 hour, P. M., of February 7th. Of the others—one-half to a fourth class, and others a third class of intermediate violence. Numerous tremors, detected by pendulums and lesser tremors may constitute a fifth class.

Dr. Drake makes the following general remarks:—

1. The original focus of these concussions was the valley of the Mississippi, between New Madrid and Little Prairie, N. Lat. 36° —W. Long. from Washington $12^{\circ} 30'$. But after the second year of their duration they seem to have ascended the Mississippi to the Ohio, then up that river 100 miles to the U. S. Saline, at which place shocks were felt nearly every day for nearly two years.
2. They were more numerous during the same period on the Mississippi than on the Ohio.
3. The shocks at Cincinnati, which have been referred to the first and second classes, were generally the most violent on the Mississippi.
4. The convulsions on the Mississippi were different from those felt at Cincinnati. Those at Cincinnati were undulatory. Those on the Mississippi seem to have been vertical.
5. The convulsion was greater along the Mississippi, as well as along the Ohio, than on the uplands.
6. All the principal shocks on the Mississippi were attended or preceded by an explosive sound, denominated by the people of that region subterranean thunder. This noise was generally heard to the southwest, which some ascribe to the low country in that direction.

7. The stronger shocks of this great series were felt in every part of the United States; and their violence generally in inverse ratio of their distance from the focus. Earthquakes were experienced, during the same years, but not on the same days, in Europe, the West Indies and South America.

8. As the time is different in different places, of solar and mean time, it is difficult to determine the precise date of any of the shocks, but their *absolute* time in every part of the United States was nearly the same. Shocks were felt in June, 1812, at Shawneetown, Ill., at Kaskaskia and on the Wabash, 40 miles from its mouth.

About the time of the New Madrid earthquake J. J. Audubon, the celebrated ornithologist resided at Hendersonville, Ky. In November, 1812,* while riding in western Kentucky he heard a noise like distant thunder, on which he spurred up his horse, but he stopped and planted his feet, with caution, on the ground, then he fell to groaning piteously, hung his head, spread out his four legs, as if to save himself from falling, and stood stock still continuing to groan. The ground rose and fell in successive furrows, like the ruffled waters of a lake. It all lasted but a few minutes, and the heavens brightened as quickly as they had become obscured, and the horse brought his feet to their natural position, raised his head and galloped off. Shocks succeeded almost every day for several weeks gradually diminishing into mere vibrations. At a friend's house on the occasion of a wedding, the company retired after frolicking awhile, but near morning the shock of an earthquake was felt and all hurriedly rushed outside in great terror, and almost nude, men and women. The earth waved like a field of corn before the breeze, but it was soon over.

Wetmore, in his *Gazetteer of Missouri*, 1837, mentions a Mr. Walker being accompanied by a Frenchman on a trip near New Madrid when the first great shock was felt. The trees tossed to and fro, the earth rocked, he fell to the ground and called the Creator to protect him. The Frenchman exclaimed, "Monsieur Walkare, no time for pray! Sacre Dieu! gardez-vous le branch," and a shower of limbs fell.

Sir Charles Lyell in *Principles of Geology*, Vol. I, p. 453, speaks of the "sunk country" ten miles west of New Madrid, and says that it extends along White Water and its tributaries for seventy or eighty miles north and south and thirty miles east and west. Throughout this area are innumerable submerged trees, some standing leafless, others prostrate. In March, 1846, he skirted the borders of this district nearest to New Madrid and noticed many submerged trees, also countless rents in the adjoining dry alluvial plains, formed in 1811-12, but still open although much changed by rains and

**Life of Audubon*; G. P. Putnam, New York, 1879. He speaks of time being 1812; if so, it is one of the later shocks.

river inundations. He also observed numerous circular cavities called sink holes from ten to thirty yards wide and twenty feet or more deep.

Humboldt in his *Casmos* (quoted in second vol. of Lyell's principles) says that the New Madrid earthquake presents one of a few examples on record of the incessant quaking of the ground for several successive months, far from any volcano. The direction of the fissures varied from 10° to 45° west and north and were often parallel. Lake Eulalie, near New Madrid, 300 by 400 yards, was suddenly drained. All the trees growing on its bottom were less than 34 years old and consisted of cottonwood, willow, horny locust, different from those growing on higher grounds, now elevated by 12 to 15 feet. On them are hickory, black oak, gum and white oak of more ancient age.

An interesting account of the earthquake may be found in Casseday's *History of Louisville, Ky.*, Ch. V.

On the 16th of Dec., 1811, at 2:15 A. M. a shock was felt at Louisville, Ky., the details of which were noticed and written out by Jared Brooks and first published in 1819 in Dr. McMurtrie's "History of Louisville." Mr. Brooks said that it seemed as if the surface of the earth was afloat and set in motion by a slight application of immense power, then a boiling action succeeds, houses oscillate, gables and chimneys of many houses are thrown down. From the earliest tremor to the last oscillation was about four minutes. This was followed by two other shocks during the same day, and of almost equal power. During the prevalence of earthquakes it was customary to suspend an object to act like a pendulum to determine the amount of danger, any time at Louisville. It occurred at 3:15 A. M. and was preceded Brooks refers to that of February 7, 1812, as the most violent felt at any time at Louisville. It occurred at 3:15 A. M. and was preceded by frequent slight motions for several minutes. The duration was about four minutes, then gradually moderated by lesser shocks for about two hours; these were followed by a succession of distinct tremors or jarrings at short intervals until 10 A. M. when there occurred a severe shock, after which there were frequent jarrings and slight tremors during the day, at least one every ten minutes. At 8:10 P. M. there was a shock of second-rate violence and soon after two others connected by a continual tremor of considerable severity. The last shock was violent in the first degree but of too short duration to do much injury. At 10:10 P. M. there were violent shocks of the second degree increasing to tremendous, and for seven seconds, then tremulous, then severe for five minutes followed by frequent tremors and a shock of third-rate violence. The action then ceased for a while. Mr. Brooks gives a table of violence and time of shocks:

1. Tremendous destruction of town, oscillation of buildings and grinding against each other, walls split and begin to yield; chimneys, parapets and gables break and topple to the ground^d.
2. Less violent, but very severe.
3. Moderate but generally alarming.
4. Perceptible to those who are still.
5. Not described.
6. Although often causing a strange sensation, sometimes giddiness, only perceptible by vibrations. Mr. Brooks gives following table:

CLASS							
End of each week	1	2	3	4	5	6	Total
December 22	3	2	3	1	12	66	87
" 29	0	0	0	0	6	150	156
January 5	0	1	2	9	3	119	134
" 12	0	1	0	10	0	150	161
" 19	0	0	0	4	6	55	65
" 26	1	1	7	2	2	78	91
February 2	1	0	4	6	7	191	209
" 9	3	5	7	5	15	140	175
" 16	0	0	3	6	22	65	86
" 23	0	0	4	6	4	278	292
March 1	0	0	1	4	8	126	139
" 8	0	0	2	9	8	39	58
" 15	0	0	2	3	6	210	221
Total	8	10	35	65	89	1667	1874

In the History of Missouri, by Lucien Carr, in the Commonwealth series, we find an interesting account of the New Madrid region. Carr states during the winter of 1812 and 1813 the people lived out in tents, being afraid to stay in their houses, also that trees were felled in many places at right angles to the chasms, to which they went whenever a shock was felt. Congress was appealed to and passed an act giving other lands to those who had lost by the earthquake. But it proved to be of little benefit to the needy, for most of them sold out their claims at a small figure which is said to have averaged less than ten cents an acre. Out of 516 certificates issued, only twenty were located by the original claimants. Others made false oaths, and 142 false claims were confirmed. Congress afterwards passed an act granting all outlots and lands adjoining the towns in the earthquake region should be given to said villages for the support of their schools.

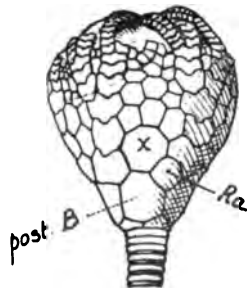
ON THE CRINOID GENERA SAGENOCRINUS, FORBESIOCRINUS, AND ALLIED FORMS.

By FRANK SPRINGER, East Las Vegas, New Mexico.

I have had for several years a unique Upper Silurian crinoid from the Niagara shales at Waldron, Indiana, which furnishes an interesting accession to the list of rare genera that have been found common to the western Niagara of the United States and the Wenlock limestone of England and Sweden. Several of them have been pointed out by Prof Weller in his interesting paper on "The Silurian Fauna interpreted on the Epicontinental Basis" (Journal of Geology, VI, p. 672). To these may be added *Barrandocrinus*, one of the most extraordinary crinoids of the Gotland rocks—almost as highly specialized as *Crotalocrinus*—which I have no doubt is represented in our Upper Silurian by the species described by S. A. Miller as *Cylicocrinus canaliculatus*, Geol. Surv. Indiana, Vol. 18, Pl. V, figs. 13, 14; also *Gnorimocrinus*, which I have obtained from Tennessee.

The specimen above mentioned makes the further addition of the genus *Sagenocrinus*, well known by its typical species, *S. expansus*, both in England and in Sweden. I call attention to it now partly for this reason, and partly as a text for some observations upon the generic relations of this and allied forms. It is apparently a distinct species, and I propose for it the specific designation—

Sagenocrinus americanus, n. sp.



Sagenocrinus americanus

Calyx elongate-pyriform, with straight sides. Calyx plates smooth, not convex, and mostly flush with the general curvature. Infrabasals and basals large. Primibrachs two. Arms proportionally small and

slender. Interbrachial spaces not depressed, filled with closely fitting plates in several ranges. Anal side differing from the others by its distinctly greater width and more numerous plates; by the presence of a large anal plate resting upon the posterior basal; and of a radianal, lying between the upper corners of the two basals, and about half way under the right posterior radial. The anal plate *x* is supported in the angle formed by the radianal and the posterior basal. Sutures in the radial series and arms strongly arcuate, and patelloid processes prominent. Stem composed of alternate thick and thin plates except near the calyx, where there are several thick ones in succession, without any marked taper.

Some specimens from Dudley, England, strongly resemble this species in the straightness of the sides and flatness of the plates; but they lack the patelloid processes, and the position of the radianal is different. In the English specimens the radianal enters the basal ring and rests upon the infrabasals; while here, instead of entirely separating two basals, it rests between their upper corners, and does not touch the infrabasals. If this should prove constant in a number of specimens, it might require their separation generically from the typical species, *S. expansus*; but without further material this is not deemed advisable. The stem in our species agrees with that of *S. expansus* in not having the rapid taper and thin columnals at the proximal end, which is characteristic of the group generally, except a few Silurian forms.

The presence of the large radianal is the important generic character of this form. The genus *Sagenocrinus* was treated by the Austins as allied to the Actinocrinidae. Von Zittel, in 1879, placed it with the Glyptocrinidae; while Wachsmuth and Springer, in 1881, arranged it under the Rhodocrinidae. Subsequently, after seeing specimens which showed that it is not a Camarate crinoid, we referred it to the Ichthyocrinidae, being the division now called Flexibilia Impinnata, where it undoubtedly belongs. It was thought to be closely related to the form for which De Koninck and Le Hon established the genus *Forbesiocrinus*. I have since then* expressed the opinion that De Koninck and Le Hon's genus would have to be given up, and also that the American species referred to it—such as *F. agassizi*—might fall under *Sagenocrinus*. Further investigation of these forms, in connection with a Monograph of the Impinnata division of the Crinoidea Flexibilia, has convinced me that this opinion was not well founded, and that on the contrary, not only are the species described under *Forbesiocrinus* generically distinct from *Sagenocrinus*, but the

* *Urtocrinus*. Mem. Mus. Comp. Zool., Vol. XXV, No. 1, p. 71.

former genus, as established by De Koninck and Le Hon,

This genus was founded by them (Recher. Crin. Carb. Belg., p. 118) upon two specimens from the Mountain limestone of Belgium, which they erroneously identified as *Taxocrinus nobilis* of Phillips. The Belgian authors, in noting the resemblances and differences, proposed to limit *Taxocrinus* to those species which do not possess interradians (interbrachials), and of which the calyx consists exclusively of basals and first radials;—thus leaving their new genus to differ from it in the possession of interradians. *Taxocrinus* was clearly not so restricted by Phillips in establishing the genus, for he included in it several species which have a greater or less number of interradians (interbrachials of current terminology); and on this character alone it would not be practicable to separate the new genus. But in the description, and in the diagram accompanying it (p. 119), there is plainly shown a structure which will distinguish it sharply, not only from *Taxocrinus*, but from nearly all other genera of this group yet found,—and that is the anal side: There the posterior basal, instead of bearing directly a prominent, vertical row of anal plates—as in *Taxocrinus* and *Onychocrinus*—is angular above, and supports two anal or interbrachial plates succeeded by others in several series, filling up the posterior interradius with solid plates. It has no radianal as in *Sagenocrinus*. The arms are isotomous, branching by regular successive bifurcations, instead of by lateral ramules from two main arm divisions as in *Onychocrinus*. These characters appear to be very constant in *F. agassizi* and other American species, except that sometimes there is a large anal plate interposed between the posterior basal and the succeeding two plates; this plate, when it occurs, is angular above, like the posterior basal in the regular form, and is followed by other plates in two or more series, filling the area. Whenever the anal side is observable there is little difficulty in separating these forms from *Taxocrinus* and *Onychocrinus*. *Sagenocrinus* differs in the calyx from *Forbesiocrinus* as *Thenarocrinus* from *Cyathocrinus*.

It is unfortunate that De Koninck and Le Hon supposed the Belgian specimens to be *Taxocrinus nobilis*, and took that species as type of the genus,—since, so far as we can judge from

the description and specimens available, it does not possess the structure of the anal side characteristic of their genus.

Some years ago I examined Phillips' type specimen in the Gilbertson collection in the British Museum. The plates of the anal side were not well preserved, but it seemed to me clear that the area had not been filled by plates resting on an angular posterior basal, as in the Belgian species. The two interbrachial areas visible contain one or two plates, and they are very different from the anal side, which is much wider, and presents the appearance of having been occupied by a vertical series of plates on a truncate posterior basal, with probably small, irregular ones at the side, as in the American species of *Taxocrinus*. *T. egertoni*, the first species arranged by Phillips under *Taxocrinus*, has at least one interbrachial, but the anal side is not shown; and the same may be said of *T. macrodactylus*, his third species. They are Subcarboniferous species,* like *T. nobilis*, and it seems probable that they possessed a similar anal side,—though *T. egertoni* has rather the appearance of an *Onychocrinus* in its very long rays. The fact that De Koninck and Le Hon erroneously identified *T. nobilis* with their Belgian specimens, and took the specimens thus incorrectly referred to that species as typical of their genus, does not, in my opinion, make the true *T. nobilis* the type of the genus, notwithstanding their statement to that effect. It seems to me a far better course to take as type the form and species which they actually described and figured, for that is the best evidence of what they intended and understood. Thus the real type of the genus is *Forbesiocrinus nobilis* De Koninck and Le Hon (not Phillips).

The subject is further complicated by a remark of Wachs-muth and Springer (Mon. Crin. Cam. p. 77) to the effect that the Belgian species belongs to *Onychocrinus*. This was based upon a specimen obtained from Belgium which was thought to show the anal plates and arms as there stated. After having thoroughly freed the specimen from the matrix I find that the observation was not correct, but that it has the angular posterior basal followed by two anal or inter-brachial plates, just as in De Koninck and Le Hon's description, and as appears in *F. agassizi* and other American

* *Whidborne* (Mon. Dev. Fauna, 1898, vol. iii, pt. III, p. 215) gives *T. macrodactylus* as Devonian.

species; and that the arms are isotomous. The rays in this specimen are unusually long, and the patelloid processes in the proximal plates scarcely visible, giving it a strong superficial resemblance to some forms of *Onychocrinus*. Yet the arms branch throughout by nearly equal bifurcations as in *Forbesiocrinus* and *Taxocrinus*, and not by means of lateral ramules as in *Onychocrinus*. This mode of bifurcation may be seen in De Koninck's figure 2a. The genus *Forbesiocrinus*, therefore, being really founded on good distinctive characters clearly set forth in the description, though not the one specially mentioned by the authors, is entitled to stand,—the type being, as before stated, *F. nobilis* De Koninck and Le Hon, and not *Taxocrinus nobilis* Phillips.

A further question has to be considered in connection with *Taxocrinus*:—The Upper Silurian species, *T. tuberculatus* Miller, from Dudley, England, has been hitherto cited as a good representative form of the genus, and is one of the four species referred to it by Phillips. It now appears, from a study of a large series of specimens, that it belongs to a type so very different from the other species as to require the recognition of a new genus for its reception. It has what looks like an extra primibrach in the right posterior ray, *i. e.* a radial followed by three plates in the series, instead of two, as in the other four rays. This appearance is caused by the fact that the two lower plates in the ray are the representatives of a compound radial, transversely divided, the lower half being a radianal, located in its primitive position as infer-radial, resting upon the basals and directly under the super-radial. This is clearly demonstrated by eleven specimens in my possession showing the right posterior ray, all of which exhibit this structure. Goldfuss' figure (Petref. Germ., Taf. 58, fig. A,) which was copied by Pictet, does not show it; but Quenstedt, who also copied Goldfuss' figure A, gives an original figure of the posterior side of another specimen from Dudley, in which the extra plate in the right posterior ray is perfectly plain (Handb. d. Petref., Taf. 75, fig. 11). It appears in the figure on the left side; but it must be remembered that the figure is reversed, so that what is really the right posterior ray appears as if it were the left.

The condition thus presented is precisely that of the inadunate genus *Dendrocrinus*; and we find that there is in

this group a series of generic forms, based on the migration and disappearance of the radianal, parallel to that occurring in the Inadunata. For we have *Sagenocrinus*, like *Thenarocrinus*, with the radianal located between two basals, and resting under the left half of the right posterior radial; the present form, *T. tuberculatus*, like *Dendrocrinus*, with the radianal lifted out of the ring of basals, and resting upon them directly underneath the right posterior ray; *Gnorimocrinus*, like *Botryocrinus*, with radianal resting on basals, but reduced in size and shifted to a position under the left corner of the right posterior radial; and *Taxocrinus*, like *Cyathocrinus*, with the radianal entirely eliminated.

Phillips' definition of *Taxocrinus* was in very general terms. The truth is that what he recognized under this name was the type which belongs to the *Flexibilia Impin-nata*, as distinguished from the Inadunata, and he did not really define any generic type limited as we now understand it. It was a parental form, just as *Poteriocrinus* and *Actinocrinus* were in their respective groups. His figures and descriptions of the species referred by him to the genus show plainly enough the general type which he recognized, but it is not so easy to determine what precise form of it should remain under his genus. If De Koninck and Le Hon's proposal for restricting the genus to species without interradianals were accepted, and it would exclude nearly all of the species referred to it by Phillips, and the result would be simply to substitute their genus for his. Phillips did not designate any species as the type of the genus, but named four as belonging to it,—three of them described by himself. His first named species, *T. egertoni*, so far as can be judged from the figure and description, is doubtful, and may belong to *Onychocrinus*, which, however, has the same anal structure. But his other two species, *T. nobilis* and *T. macrodactylus*, seem beyond question to be of the type which has been taken by the later authors generally to be that of *Taxocrinus*, viz: with few or no interbrachials, and anal plates in a vertical series supported on a truncate or excavate posterior basal, probably forming a small tube. This is substantially the definition adopted by Mr. Bather in Lancaster's Treatise on Zoology, Part III, p. 189.

numerous *Sagenocrinus*.

Arms heterotomous; iBr few; large anal α followed by other irregular plates; 10 main arm-branches with branching ramules inside of dichotom. *Lithorcrinus*.
20 main arm-branches, with simple ramules inside of dichotom. *Aristocrinus*.
Dactylocrinus.

Arms isotomous; iBr few..... *Gnorimocrinus*.

Arms isotomous.
Arms simple *Rhopalocrinus*.
Arms branching; anals in tube-like
row *Taxocrinus*.

Arms heterotomous; bearing ramules.
 Ramules unilateral.
 On inside of dichotom, 20 main
 branches *Syncrocrinus*.
 On outside of dichotom; 20 main
 branches *Oligocrinus*.
 Ramules bilateral, branching in clus-
 ters alternately on both sides of 10
 main arm branches *Onychocrinus*.

3. Anal side not distinct.
Arms heterotomous; simple ramules on inside of 20 main arm-branches; may have iBr *Wachsmuthicrinus*
Arms isotomous; iBr not filling distal face of radial *Nipterocrinus*.

Some of Angelin's Silurian genera are arranged with doubt, especially the very irregular *Calpiocrinus*. In some specimens the arms abut closely; in others they are considerably divergent. I have specimens from Dudley, identified as *C. cratus*, which have the basals very plain, and show a small radial directly under the right posterior radial; in the Gotland specimens I can see no trace of this, but the basals are entirely overgrown and concealed by the infra-basals. This Dudley form may belong to a new genus; if so it may take the name *Leiocrinus*, and will fall under the Taxocrinidae, next to *Sagenocrinus*.

Aristocrinus may have to give way to *Dactylocrinus*; both seem to be founded on the same generic type.

Unless two of Angelin's species, *T. distensus* and *T. rigens*, are really without radianal, all the unsymmetrical *Taxocrini* belong to the Silurian. That is the case in America, where the form from New York and also that from Tennessee, fall under *Gnorimocrinus*.

The second family might perhaps be subdivided into two sub-families, embracing the sub-groups 1 and 2 as *Sagenocrininae* and *Taxocrininae*.

The new genus *Wachsmuthicrinus* mentioned in the foregoing table, is proposed in memory of my lamented colleague, Dr. Charles Wachsmuth, for the reception of certain species of *Taxocrinidae* which are distinguished by the absence of any anal plates. They hold somewhat the same relation to the family *Taxocrinidae* that *Ichthyocrinus* does to the *Ichthyocrinidae*, although, unlike that genus, they may possess interbrachials. The type is one of the best known species in the Lower Burlington limestone, always a favorite with the local collectors, described by Hall as *Forbesiocrinus thiemci* (Bost. Jour. Nat. Hist., VII, p. 317).

The genus *Parichthyocrinus* is founded upon the species described by Wachsmuth and Springer as *Ichthyocrinus nobilis* (Proc. Acad. Nat. Sci. Phil., 1878, p. 254). Specimens since discovered show that it has a distinct anal side, with a vertical row of plates bordered by small irregular pieces connecting it with the adjacent rays, as in *Taxocrinus*. It is an interesting intermediate form near *Ichthyocrinus*, having the abutting arms of that genus, combined with the anal side and interbrachials of *Taxocrinus*.

The genus *Oligocrinus* is established for the reception of the form described by Hall as *Forbesiocrinus asteriacformis* (Bost. Jour. Nat. Hist. VII, p. 320), and hitherto referred to *Onychocrinus*; from which, as well as from all others of this group, it differs in having the ramules only on the outside of the dichotom. It is the earliest of the *Onychocrinus* type, which later assumes an alternate mode of branching, first by short clusters and finally by ramules, simple or branching, given off alternately from every second brachial. In this bilateral and alternate mode of branching may be

seen a decided tendency toward pinnulation, which may lead up to the Pinnulate division of the Flexibilia.

The Flexibilia Impinnata form a compact, well defined group; limited, so far as we know, to Palaeozoic time. The two families of this group range from the Lower Silurian to the later Carboniferous; and they exhibit, to some extent, a succession of parallel modifications. There is a general tendency from irregularity toward regularity in the calyx structure. The radianal, which is well developed in Silurian genera of both families, disappears from both in the Carboniferous. Bilateral symmetry, as characterized by the presence of a tube-like series of anal plates, is carried through almost the entire Palaeozoic in *Taxocrinus*, and is perhaps most strongly marked in one of the latest developed and latest surviving genera—*Onychocrinus*. As occurs in other groups, the simplest form of all—*Ichthyocrinus*—with a perfectly symmetrical calyx, without interbrachials, is the longest lived genus, ranging from the Silurian to the Coal Measures; and is the last survivor of the group, so far as at present known.

In studying this group, I have found a most remarkable example of recuperation. It is a *Taxocrinus*, in which the entire calyx, with the exception of the infrabasals and one basal, has been broken off during life and restored by new growth. The stem and plates above mentioned are those of a medium sized crinoid, while the recuperated calyx is that of a very young one. There is considerable irregularity; *e. g.* it has six rays, one having apparently been developed on the anal side. This is the first instance of recuperation of more than a ray that I have observed among fossil crinoids. Danielsson, in his Report on the Crinoidea of the Norwegian North-Atlantic Expedition of 1876-8, has described three specimens of *Bathocrinus carpenteri* from the Arctic ocean, in which recuperation of the crown upon the basals has taken place.—thus producing the crown of a very young crinoid upon a very mature stalk and basal ring (*Op. cit.* pp. 11-13, Pl. III, figs. 1-2; 3-4; 5-6).

NOTICE OF A NEW COMATULA FROM THE FLORIDA REEFS.

By FRANK SPRINGER, East Las Vegas, N. M.

Among the fine collections made by the Bahama Expedition of the State University of Iowa in 1893, under the direction of Prof. C. C. Nutting, there are some specimens of a somewhat remarkable form of the comatulid genus *Actinometra*, which were courteously placed in my hands for description. They were found at the Dry Tortugas, living at a depth of three feet. The form seems to differ decidedly from all other described species, and is of such special interest that it has been thought best to give a preliminary notice of the occurrence, in advance of a more detailed account now in preparation, which will appear in the Natural History Bulletin of the State University of Iowa. The species is large,—having a spread of about 27 cm.,—with the marginal mouth, central anal tube, and combed pinnules characteristic of the genus. It belongs to the group Fimbriata, which are characterized by having the first syzygy in the arms between the second and third brachial. But this differs from the other species of that group, and from all others of the genus as well, by having a calcified ambulacral skeleton composed of alternating covering-plates in the arms, and to some extent in the pinnules. The absence of plated ambulacra has been regarded as one of the peculiar characters of the genus *Actinometra*, whereby it was sharply separated from *Antedon* and the Pentacrinidae, and in fact from all other crinoids, recent and fossil, except the Cretaceous genus *Uintacrinus*. The occurrence of these specimens, living in the shallowest water yet recorded for any crinoid, and possessing all the characters of the genus in a marked degree, with this important exception, is a fact of much interest to students of the group. I have proposed for the species the name *Actinometra iowensis*.

**GEOLOGICAL AGE OF CERTAIN GYPSUM
DEPOSITS.**

By CHARLES R. KEYES, Des Moines, Ia.

In his excellent report on the geology of Webster county, recently issued by the Iowa Geological Survey, Prof. F. A. Wilder ably argues for the Permian age of the Ft. Dodge gypsum beds. In this argument several very important phases of the problem appear to be entirely overlooked.

At the time the special report on the gypsum deposits of Iowa was published, the history of opinion on their geological age was summed up, and reasons given for believing that the beds in question were laid down in time subsequent to the Paleozoic. Since that report was issued, the orogenic history of the region has become more clearly understood. The ancient physiography of the district has been deciphered in a way that proved far more complete than was anticipated. It is to some of these phases of the question that attention is now called; but to which Mr. Wilder gives no intimation. The evidence appears to prove beyond all reasonable doubt that the Ft. Dodge gypsum is not of Paleozoic age.

It is quite manifest that Mr. Wilder has misunderstood some of the chief statements urged, in the special report referred to, for the post-Paleozoic age of the Ft. Dodge gypsum. This fact has in a measure led to arguments which otherwise might not have been made in regard to the Permian age of the gypsum beds.

Even casual consideration of the arguments set forth for the Permian age of the Iowa gypsum clearly indicates that in reality no critical data were obtained. Some of the points brought up are among the most forceful in demonstrating directly the opposite of what was intended. Attention called briefly to these statements will render more comprehensive some of the facts discussed.

The fact that the shales accompanying the Ft. Dodge gypsum have a pale reddish to pinkish color appears to have suggested the "Red-beds" of Kansas, so often referred to the Permian. It seems that the color association of the formations of the two localities was suggested by a perusal of the literature rather than actual comparisons in the field. The Kansas "Red-beds" are entirely different lithologically from the

gypsum shales of Iowa. Moreover, it is quite certain that the "Red-beds" of Kansas are not all of Paleozoic age. From a purely lithologic standpoint, if the comparison has any value at all, the closest analogue of the Ft. Dodge gypsum shales is to be found in the nearest Tertiary deposits of the region. It is not at all improbable that the Iowa gypsum may have to be eventually referred to so late a date as the Eocene. Until fossil data are secured there may long exist very strong grounds for regarding the beds in question as possibly Tertiary.

The hypothesis of arid climate during the so-called Permian period appears to have far too slender basis to be of much real service in determining the possible contemporaneity of the Kansas and Iowa gypsums. In fact, so far as the information actually acquired goes the genesis of the Ft. Dodge gypsum and associated shales do not demand necessarily an especially arid climate. Neither does the fact that fossils have not yet been found in these deposits argue for aridity during the period when the gypsum was supposed to be forming. No real effort has ever been made to search for fossils in shales overlying the gypsum. Personal examinations have led to the belief that the field is a favourable one for the finding of organic remains. The lacustrine gypsum formations of the Paris basin appear at first glance as uninviting for fossils as the Iowa beds; but an extensive array of vertebrate remains has been found there, together with land shells and plants. Underneath, too, are other gypsum beds of marine origin, carrying in the associated shales a considerable fauna.

The elaborate table showing the gypsum deposits of the world is deceptive so far as indicating that the principal gypsum bodies of the world are found in Permian strata. Instead of the 10 great districts mentioned as Permian there should be in reality only two. Texas, Oklahoma, Indian territory and Kansas practically belong to a single field in place of four; and some of the most important gypsum deposits of these states are of later age than Paleozoic. The same may be said of the great Russian gypsums.

In this connection it may be stated that it is questionable whether the term Permian is applicable to any American strata. The original Permian is at best only a provincial series. In this country the main beds to which the title has been given

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appear to belong to two taxonomic groups of serial ranks. Names have already been given to these terranes, so that at best the term Permian seems to be superfluous, and will probably have to be dropped altogether as a geological title.

The fact that the gypsum deposits have not as yet yielded fossils does not militate in the least against correlation with fossiliferous terranes of other Iowa localities. If the beds were to be paralleled with those of the Niobrara, for example, we would not expect, necessarily, to find the same fossils in both; we would naturally be somewhat surprised if we did not come across species that were not identical. The difference in local environment would demand very different faunas in the two localities. All evidence as to age or sequence based upon fossils must for the present be excluded, because organic remains, while they no doubt exist in the gypsum shales, and perhaps abundantly, have not yet been reported.

In looking about for critical criteria bearing upon the age of the Ft. Dodge gypsum deposits we find that the marked unconformity at the base of the formation is a feature that is stratigraphically of first importance. Its physiographic connections when established must appear exceptionally trustworthy as data by which to determine the geological age of the deposits immediately overlying. In the region under consideration there are two great horizons presenting marked evidences of unconformity. One is at the base of the Cretaceous; and the other is at the base of the Eocene.

Between the Cretaceous plane of unconformity and the one at the bottom of the Des Moines series (Lower Coal Measures) no notable level of unconformity is known. Sedimentation appears to be uninterrupted through all of the Paleozoic above the Mississippian. Throughout all of the 3500 feet of Paleozoics represented by the Des Moines, Missourian, Oklahoman (so-called Permian) and Cimarron series, the levels of evident peneplanation seem wanting. In western Iowa, if the Ft. Dodge gypsum deposits belong to the "Permian," there is to be accounted for a stratigraphic interval of between 2000 and 3000 feet, even when the nearest and lowest of the Kansas deposits is considered. The stratigraphic position of the basal horizon of the so-called Permian of Kansas is at the lowest calculation more than 2000 feet above Ft. Dodge. There are at the present time not the slightest grounds for

believing that any part of this great section was removed through erosion during the Paleozoic times.

In the distance of 200 miles, as the crow flies, between the nearest Kansas and Iowa gypsum beds there is a bevelling of strata which begins some distance west of the first named locality and at a stratigraphic level considerably higher, and extends northeastwardly beyond Ft. Dodge and stratigraphically below the rocks in which the gypsum of the last mentioned place lies. This bevel-plane represents Cretaceous peneplanation. The Kansas gypsum lies below and entirely without. The Iowa gypsum lies immediately above the level where this Cretaceous plane should emerge at the present surface of the ground. Fort Dodge is on the eastern boundary of the Cretaceous in Iowa. It is also exactly at the point where the Cretaceous peneplain, bevelling the Paleozoics at a given angle, is cut by the Tertiary peneplain, bevelling both Paleozoics and Mesozoics at a very different angle.

If the so-called Permian deposits ever existed over the present site of Ft. Dodge they were long since removed by Cretaceous erosion, and more than 2000 feet of other Carboniferous sediments besides. Even if the Permian of the region had escaped Cretaceous erosion, there was still Tertiary erosion to remove it, and the Coal Measures, down to the same level.

The assignment of a Permian age to the Ft. Dodge gypsum deposits appears to be entirely precluded by all direct evidence available. The only question regarding the geological age of these beds seems to be whether they are Cretaceous or Tertiary; not whether they are Cretaceous or Carboniferous. On the first mentioned point there have been as yet no direct data obtained. In the special report upon the Iowa gypsum deposits, published seven years ago, I endeavored to present the facts which were thought to be conclusive proof of the post-Paleozoic age of the beds. In urging this opinion I perhaps unconsciously emphasized too strongly and too specifically the Cretaceous aspects of the problem.

A Cretaceous age for the Ft. Dodge gypsum deposits appears the most probable at present writing, especially when the problem is viewed in the light of physiographic criteria. A Tertiary age for these beds is not beyond a possibility. A Permian age seems entirely impossible.

GROWTH OF THE MISSISSIPPI DELTA.

By WARREN UPHAM, St. Paul, Minn.

In a recent study for the Minnesota Historical Society, on the "Progress of Discovery of the Mississippi River," I have consulted the narrations of the earliest expeditions observing the Mississippi at its mouths, and of the discoveries of this river by white men through the various parts of its course from lake Itasca to the Gulf of Mexico. This research has brought together information of the growth and changes of the delta and mouths of the Mississippi, which are of much geological as well as historical interest. It is also ascertained that the course of navigation entering the Mississippi from the Gulf of Mexico, or going out from the river, in all instances definitely identifiable previous to 1699, was by way of the Bayou Manchac, not by the river's mouths in the delta. The first description of the delta, passes, and mouths, is therefore derived from La Salle's canoe expedition down the Mississippi in 1682. It will be desirable, however, to glance at the earlier discoveries of the Mississippi or its mouths; and these carry back a cartographic record to the end of the fifteenth century, a little more than four hundred years ago.

According to Varnhagen, the Brazilian historian, and John Fiske's "Discovery of America," with whom I fully agree, Amerigo Vespucci's first voyage to the western hemisphere, made in 1497-98, apparently as pilot and cartographer of an expedition commanded by Pinzon and Solis, concerning which much doubt and misunderstanding had existed because of the lack of many details in Vespucci's narration, was the source of the first mapping of Yucatan, the Gulf of Mexico, and Florida. In Vespucci's chart of that very early date the Mississippi river was unmistakably delineated, with a three-mouthed delta extending into the gulf. This delineation is preserved by Waldseemüller's map, entitled "Tabula Terre Nove," drafted probably after 1504 and certainly not later than 1508, which was published at Strasburg in an edition of Ptolemy in 1513. It gives a distorted outline of the Gulf of Mexico, with a large river emptying into it by three mouths, pushing its delta far into the gulf, in which respect the Mississippi surpasses any other river, this being indeed the most remarkable

feature of its embouchure. Vespucci sailed past this delta early in the year 1498, surveying the mouths of the river from the masthead, or very likely entering the river and spending some time there; but we have no record of it, excepting the general and in this part vague account of the voyage, as written by Vespucci, and the map by Waldseemüller showing the projecting delta and three chief passes and mouths of the Mississippi.

Alonso Alvarez de Pineda, in 1519, led an expedition of three or four sailing vessels to explore the northern coast of the Gulf of Mexico. The resulting map, transmitted to Spain, gives a somewhat correctly proportioned outline of the entire gulf, with Florida, Cuba, and Yucatan inclosing it on the east; and the Mississippi is named Rio del Espiritu Santo (River of the Holy Spirit). In Harrisse's *Discovery of North America* (1892, p. 168), a translation from the contemporary Spanish account of this expedition says, concerning the Mississippi, that the ships "entered a river which was found to be very large and very deep, at the mouth of which they say they found an extensive town, where they remained forty days and careened their vessels. The natives treated our men in a friendly manner, trading with them, and giving what they possessed. The Spaniards ascended a distance of six leagues up the river, and saw on its banks, right and left, forty villages."

Pineda's map shows the Mississippi as if it had a wide mouth, growing wider like a bay in going inland, and it has no representation of the delta; but this river and the several others tributary to the gulf are all mapped only at their mouths. What he meant for the Mississippi is more clearly indicated by the map sent to Spain by Cortes and published there in 1524, which shows the Rio del Espiritu Santo flowing through two lakes close to its mouth, evidently intended to represent lakes Pontchartrain and Borgne. The same delineation of the lower Mississippi is given also by the Turin map, of about the year 1523. Both these maps, doubtless based on information supplied by Pineda, display the course of the Mississippi above lake Pontchartrain to a distance of apparently at least a hundred miles, where it is represented as formed by three confluent streams. Through questioning the Indians, he probably learned of the Red river, and of its northern tributary, the

Black river, which would be the two inflowing streams at nearly the distance mentioned from lake Pontchartrain.

The little ships of Pineda's expedition therefore must be supposed, according to these maps, to have entered the Mississippi by one of its outflowing navigable bayous, which, before the construction of levees, discharged a considerable part of the waters of the great river through lakes Maurepas, Pontchartrain, and Borgne. The Indian town described at the mouth of the river may have been at the mouth of the bayou, that is, on or near lake Maurepas; or it may have been near the chief place of outflow from the main river, which most probably then, as now, was at the Bayou Manchac, 117 miles above the site of New Orleans by the course of the river, and 14 miles below Baton Rouge. There is no reason to distrust the statement that within six leagues thence up the Mississippi the Spaniards observed forty groups of temporary or permanent Indian dwellings. If the ships only entered the mouth of the bayou (or of the Amite river, through which it sends its waters to the lake), being there careened and repaired, it is easy to infer that some of the Spaniards ascended the Amite river and the Bayou Manchac in small boats to the Mississippi, noted the width of that mighty stream, sounded its great depth, and reported its Indian villages. The delta, jutting out as a long cape, was neglected by Pineda in his mapping, which was accepted generally by cartographers. The chart of Vespucci's first voyage, more truthful as to this river's embouchure, had been lost and forgotten.

In 1528 one of the mouths of the Mississippi was seen in the forlorn last voyage of Pamphilo (or Panfilo) de Narvaez, who tried in vain to stem its current and enter it. All that we know of his fate is from the narrative of Cabeza de Vaca, one of the very few survivors from their shipwrecks, who, after eight years of hardships and wandering among the Indian tribes, reached the Spanish settlements in northwestern Mexico. No map, nor other information of this river, was received from that expedition.

When De Soto, in his grand but disastrous expedition through the area of our southern states, had crossed the Mississippi in 1541, apparently near the site of Memphis, and the next year had died at an Indian town, Guachoya, near the mouth of the Arkansas river, his followers under their new

commander, Moscoso, tried first to march west and southwest to reach Mexico; but, failing of this, and having returned to the Mississippi at Aminoya, near Guachoya, they built seven brigantines and descended this river in July, 1543.

Among the volunteers forming this expedition was a Portuguese from Elvas, well educated and probably an officer under De Soto, but whose name is unknown. After his return to Europe, he wrote a narrative of the expedition, often cited as the Portuguese Relation, which is the most complete and reliable account of it that has been preserved. A translation of it, by Buckingham Smith, from which the next quotation is taken, was published in New York by the Bradford Club in 1866. The debouchure of the Mississippi was described as follows:

When near the sea it becomes divided into two arms, each of which may be a league and a half broad....Half a league before coming to the sea, the Christians cast anchor, in order to take rest for a time, as they were weary from rowing....[Here Indians came, in several canoes, for an attack.]....There also came some by land, through thicket and bog, with staves, having very sharp heads of fish-bone, who fought valiantly those of us who went out to meet them....After remaining two days, the Christians went to where that branch of the river enters the sea; and having sounded there, they found forty fathoms depth of water. Pausing then, the Governor required that each should give his opinion respecting the voyage, whether they should sail to New Spain [the colonies in Mexico] direct, by the high sea, or go thither keeping along from shore to shore....It was decided to go along from one to another shore....

On the eighteenth day of July the vessels got under weigh, with fair weather, and wind favorable for the voyage.... With a favorable wind they sailed all that day in fresh water, the next night, and the day following until vespers, at which they were greatly amazed; for they were very distant from the shore, and so great was the strength of the current of the river, the coast so shallow and gentle, that the fresh water entered far into the sea.

Luis Hernandez de Biedma, a factor or agent for the Spanish king, was a member of De Soto's expedition, of which, after returning to Spain, he submitted a report in 1544. From the translation of that report, given by Buckingham Smith in the same volume with this narrative of "the Gentleman of Elvas," we have the following considerably different description of what was thought to be the junction of the Mississippi with the gulf.

We came out by the mouth of the river, and entering into a large bay made by it, which was so extensive that we passed along it three days and three nights, with fair weather, in all the time not seeing land, so that it appeared to us we were at sea, although we found the water still so fresh that it could well be drunk, like that of the river. Some small islets were seen westward, to which we went: thenceforward we kept close along the coast, where we took shell-fish, and looked for other things to eat, until we entered the River of Panuco, where we came and were well received by the Christians.

By comparing Biedma's report with the Portuguese Relation, I am convinced that the brigantines did not pass down the Mississippi to its delta, but went out to the Gulf of Mexico by way of the Bayou Manchac, lakes Maurepas, Pontchartrain, and Borgne, and the Mississippi sound. In other words, Moscoso, with his squadron, took the same passage that Pineda had taken, in 1519, for his entering the Mississippi. Several points in the narrations need now to be explained in detail, as to their harmony with this conclusion.

First, the Indians had villages near the Bayou Manchac; but probably there were no inhabitants near the true mouth of the river, at the end of the delta. Second, under this view, we must regard the Portuguese statement of a division of the river, into two arms or branches, as referring to the large outflow, at a time of flood, to the Atchafalaya river. Instead of receiving an inflow at the junction of the Red river, the flooded Mississippi there sent out a portion of its current, by the mouth of the Red river, to the Atchafalaya; which also, when the Red river is at a higher stage than the Mississippi, takes a part of the current of the former, carrying it south by a much shorter course to the gulf. Third, another statement of the Portuguese Relation, noting the great depth of forty fathoms where their branch of the river "enters the sea," must be then interpreted as found in the bend of the Mississippi from which the Bayou Manchac flows away. In its condition of a high flood, the river there opens toward a vast expanse of water, called, by the narrator, "the sea," reaching east over lake Maurepas and onward to the gulf. It seems indeed not unlikely that the Mississippi at that place may have then had even so great depth: for in a sharp curve at New Orleans it was found by the Mississippi River Commission to have a sounding of 208 feet.

Sailing on the wide lakes Pontchartrain and Borgne, with the very low lands inclosing the latter probably then submerged, Moscoso and his men would regard all that expanse of fresh water, reaching from the Bayou Manchac nearly a hundred miles east to the Mississippi sound, as "a very large bay" of the sea. They would consequently be surprised at the very long distance to which the Mississippi sent its waters without their becoming salt; whereas even the greatest floods could not freshen the sea very far out from the mouths of the delta. The Portuguese Relation says that the Mississippi, before the departure from Aminoya, had risen, in such a high flood, to the ground at the Indian village, where the brigantines were built, floating them; and we may infer, with good assurance, that the same flood continued, at nearly its full height, through the next two weeks, till they came to the Bayou Manchac and the vast fresh water expanse stretching thence far to the east.

Soon after this expedition was disbanded in Mexico, testimony of those who came back to Europe was taken by some unknown compiler as the basis for a revised map of the "Gulf and Coast of New Spain." It is reproduced by Harris in his great work, *The Discovery of North America*. It shows the Atlantic and Gulf coast from Georgia to the Panuco river, and extends inland so far as the country was known, however vaguely, from the explorations of De Soto and Moscoso. The Mississippi empties into the Vaya (Bay) del Espiritu Santo, which is also called Mar Pequeña (Little Sea), taking the place of the lakes north of New Orleans, and thus confirming my conclusion as to Moscoso's passage into the gulf.

A hundred and thirty-nine years passed before La Salle, on the ninth day of April, 1682, erected a wooden column and a cross near the head of the passes of the Mississippi, and, with imposing ceremonies, took formal possession of this vast river basin for France.

Leaving the Illinois river February 13th, La Salle and his company of about fifty French and Indians voyaged slowly down the Mississippi, hunting and fishing almost every day to supply themselves food, and visiting with the numerous Indian tribes. April 6th they arrived at the head of the branches or passes of the river, in the delta, where the mighty stream divided into three channels, each of which was examined and



reported to be suitable for navigation, wide and deep. The length of the western channel was noted as about three leagues. Accounts of this expedition were written by La Salle, Tonty, and Membré, and in recent times much biographic information concerning La Salle has been published by Sparks, Parkman, and Margry; but no map of the Mississippi drafted at that time has come down to us. In following all the winding course of the river, it would indeed have been a very difficult task to map it with general accuracy. It was erroneously thought to trend westward so that its mouths would not coincide with the River Espiritu Santo of the Spanish coastal charts, but rather with some other of the several rivers entering the gulf farther west.

A detailed map of the river's mouths in 1682, then probably for the first time leisurely examined by white men, would be of great interest to geologists, for a study of the subsequent extension of the delta. We must be content, however, with the few meager statements already given. Better information was gathered seventeen years later. Iberville and Bienville, brothers destined to become illustrious by founding the French colony of Louisiana, entered the eastern mouth of the delta with rowing boats, March 2nd, 1699; and in September of the same year a small English frigate entered one of the mouths and ascended the river to the English Turn, a great bend ten miles below the site of New Orleans. These are the earliest historic records of entries at the river's mouths.

The chart of the delta drafted by these early English adventurers was used by Daniel Coxe in a map published in 1722, in his "Description of the English Province of Carolana, by the Spaniards called Florida, and by the French La Louisiane." This is the earliest map showing the mouths of the Mississippi with considerable detail, the date of its information being 1699. It represents the eastern passes and the south pass as much shorter than the southwest pass, which last was described by La Salle as having a length of about three French leagues (8.28 statute miles). Coxe wrote: "The Three great Branches always Navigable by Shipping, are situated about 6 Miles distant from each other, and unite all at one Place with the main River, about 12 Miles from their Mouths."

Another detailed map of this delta, far more elaborate, by Bellin, the distinguished French engineer, was published in

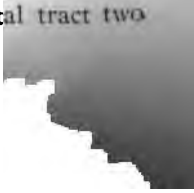
1744 in Charlevoix's great work, "Histoire de la Nouvelle France." Between the dates represented by these maps, the south pass had been much extended, while the others showed little change.

After these early dates, until 1885, when the admirable maps of the lower part of this river from surveys of the Mississippi River Commission were issued, each of the passes was extended six to eight miles into the gulf, and the eastern passes became more complex, with broad adjacent mud flats. Humphreys and Abbot, in 1861, determined the average yearly advance of all the passes to be 262 feet, which would amount to about five miles in a hundred years; and they estimated that a period of about 4,400 years has been occupied by the extension of the delta from the vicinity of Plaquemine and the Bayou Manchac.

When the delta was seen by Vespucci, four centuries ago, it probably terminated ten to fifteen miles back from the present head of the passes, where an old branching delta front is shown by the map of the Mississippi River Commission, in the continuation of the curving line of the Chandeleur islands and Breton island.

The extension of the delta from the old to the new group of branches or passes was effected evidently by the enlargement and elongation of one of the former passes far beyond the others, until it gradually became the chief channel, and was finally the only channel at ordinary stages of the river. Then, or during the latter part of that extension and widening, a new trifurcation took place at or near the end of the greatly elongated pass, there establishing a new system of distributaries, similar to the previous system that was thus abandoned and left about fifteen to twenty-five miles in the rear, its old channels being filled with river silt. Probably this process of periodic extension, new forking, and reinstatement of passes and mouths had taken place only once before the present system came into existence.

Inspecting the convex general coast line of the delta, from Mississippi sound southwestward across the present course of the river, and onward west and northwest to Atchafalaya and Vermilion bays, we see how the delta was gradually built out into the gulf to that limit, growing forward, similarly with many other deltas of large rivers, upon a curved coastal tract two



hundred miles long. Only a few centuries before the discovery of America, the principal channel was extended beyond that general and normal delta front, and acquired an abnormal or at least unique projecting termination, there emptying to the sea, as observed in 1498, by the three main passes shown in its earliest map. Once it has advanced again, as described by the preceding paragraph, nearly duplicating its first stage of projection, and thereby forming the present system of passes, which was fully established before the time of La Salle; and this system, in each of its branches, has since grown several miles outward.

The great depth of the gulf adjoining the present mouths tends to prolong this stage, and by engineering aid it may be continued many centuries. At some future time, however, instead of stretching forward in a third stage beyond these two, probably the main current will forsake this lower course, and will descend to the sea level by some shorter and easier way, as the Bayou Manchac, or the Atchafalaya river, or some other of the many bayous and small rivers that branch off from the great river throughout its delta.

LIST OF THE MOST IMPORTANT VOLCANIC ERUPTIONS AND EARTHQUAKES IN WESTERN NICARAGUA WITHIN HISTORIC TIME.

[Compiled from various sources.]

By J. CRAWFORD, Managua, Nicaragua.

- 1609. *Momotombo*, at the west end of lake Managua—and volcanic cones northwestward to and including *Cosaquena* on the peninsula of that name between the gulf of Fonseca and the Pacific ocean were in violent activity. Momotombo's ejecta burying deeply in ashes, cinders and fragments of rocks the old city of *Leon*, a large city, then the capital of Nicaragua. The locality is now the terminus of a railroad; the new city of Leon is forty miles westward.
- 1680. *Viejo* was in violent activity; the present town of Chinendega is a few miles southwest from volcano Viejo: numerous earthquakes.
- 1764 *Momotomba* again active accompanied by very severe earthquakes.
- 1772. *Masaya* very active for about 10 days; when subsiding its crater appeared to be full of a yellow substance that two Spanish

- priests decided was gold, and endeavoring to dip up the gold, lost their buckets, chains and two of their Indian assistants.
1809. *Cosaquena* active for a few days.
1835. *Cosaquena* in explosive activity blew off a large part of its cone; ashes and cinders covered the houses and streets in the city of Mexico, 1200 miles distant, and pumice stones from it covered the Pacific ocean for about 100 miles west from the volcano: a yet pulsating—opening and nearly closing fissure was opened on the western side deep enough, probably, to connect the water at present in its deep crater with the gulf of Fonseca.
1844. Series of earthquakes and eruptions from *Cosaquena*, elevating the bed of a part of the Rio Negro in N. E. Nicaragua, and also a part of the bed of Rio Tipitape, north-west from Momotombo, that connects lakes Managua and Nicaragua, so that now the water flows in that part of the channels of those rivers only during high water in the rainy season.
1841. Series of many days of severe earthquakes.
1850. Formation of the volcanic cone "*Pilas*" at the northern foot of the extensive volcanic mass Mombacho on the western margin of lake Nicaragua: the city of Granada is just north of volcano Mombacho.
1857. *Masaya* in violent eruption—also at the same time volcano San Miquel in Salvador.
1859. *Masaya* expelling streams of lava for a few days.
1862. Earthquakes, very severe, for several days, in Nicaragua and Salvador.
1865. Earthquakes numerous and severe in western Nicaragua for many days.
1870. Earthquakes from volcano *Masaya*, accompanied for a few days, with loud "grating" also "roaring" sounds.
1870. Earthquakes from *Momotombo* of great force injuring many persons and destroying many houses in the city of Leon, accompanied by very loud harsh sounds.
1883. *Ometepe*, a volcanic island in lake Nicaragua for a few days accompanied by loud grating sounds, filling with fragments of rock and sand some of the ravines that had been cut by torrents of rain about forty feet deep down to a stratum on which aborigines made coarse styles of urns, pottery, etc: a finer kind and painted pottery, urns for burying the dead, etc., were made by Aztec or Chontal invaders, on a stratum nearer the earth's surface.
1885. Earthquakes, destroying several lives and much property in cities of Leon and Chinendega, from *Vieja*.
1886. *Momotombo* in eruption: numerous earthquakes for many days.
1891. Earthquakes, numerous daily for about forty days; most strongly felt in the city of Grenada, occasioned by a disturbance beneath lake Nicaragua and a few miles north of Ometepe: reported to *American Geologist*.

1898. Earthquakes for one day, causing much damage to the "cathedral" in the city of Leon.
1901. Earthquakes numerous but not severe, reported in *American Geologist*.
1902. Earthquakes, several not very strong, reported to *American Geologist*.

There are many evidences of prehistoric violent volcanic eruptions in western Nicaragua: one is a stratum, miles in area, in the southern part of and south of lake Managua, that retains the deep impressions, on its upper surface, of human feet, grown persons and children—also of domestic animals, that evidently were fleeing into the lake to escape hot ashes from some volcano, probably Masaya; the toes of the feet all point, in each impression, toward the lake.

EDITORIAL COMMENT.

THE ORE DEPOSITS OF MONTE CRISTO, WASHINGTON.

This little monograph embodies the results of a month's study of one of the most important mining regions in the state of Washington, and presents in concise form a quite comprehensive description of its rocks and ores.*

The mining camp of Monte Cristo is situated in the heart of the Cascade range, but on its western slope. It lies nearly due east of the city of Everett and about 40 miles distant and can be conveniently reached only by the Everett and Monte Cristo railroad.

The author describes the following rock divisions as recognized in the district:

- | | |
|---|----------------------------------|
| 1. Ancient granitic rock, not exposed,..... | Mesozoic. |
| 2. Arkoses and conglomerates with some quartzites,.... | Eocene. |
| 3. Earlier andesytes and tuffs, | } Miocene. |
| 4. Tonalyte (dacite), | |
| 5. Rhyolyte, | } Late Pliocene and Pleistocene. |
| 6. Pyroxene-hornblende-andesytes, }
tuffs and volcanic breccias, | |

The granitic rocks have not been found in place, but are represented by the sedimentary deposits that have been formed from them, such as granitic arkoses and conglomerates containing coarse pebbles and boulders of granite. These granitic arkoses constitute a series several thousand feet in thickness

* The ore deposits of Monte Cristo, Washington. By JOSIAH EDWARD SPURR. Twenty-second annual report, U. S. Geological Survey, Part II, pages 779-865; plates lxxix-lxxxii, figures 89-130, 1900-1901.

of arkoses, conglomerates, quartzites and shales, and some limestone. Portions of the arkose are metamorphosed into fine-grained granitic rock, with fresh biotites and feldspars. The arkose series is cut by dikes of more recent andesyte, basalt and tonalite. The tonalite consists of feldspar, hornblende and biotite, with occasional augite and hypersthene and magnetite (?). The feldspar varies between oligoclase and bytownite, and the secondary minerals are actinolite, chlorite, epidote, pyrite, calcite, kaolin, etc. The tonalite cuts the arkose series and the early andesytes, and is cut by the later andesyte and probably also by the basalt. It is correlated with the Snoqualmie granite of Smith and Mendenhall.*

The later andesytes, tuffs and breccias are the products of explosive eruption from volcanic vents like mount Baker, mount Rainier and Glacier peak, and are supposed to belong to a period which lasted from the late Pliocene to late Pleistocene.

To this same period of volcanic eruption, profound fracturing and slight faulting, is ascribed the origin of the joints which now form the loci of the ore-bodies.

The chief ores of the Monte Cristo district are pyrite, pyrrhotite, arsenopyrite, blende, galena and chalcopryrite. Rarer minerals are chalcocite, bornite, molybdenite and stibnite, and oxidation products are malachite, limonite, hematite, melanconite and scorodite.

These ores carry relatively small amounts of gold and silver. In the Monte Cristo mine the average ore at some distance below the surface carries 0.6 of an ounce of gold and 7 ounces of silver. The richer ores carry 1.4 ounces of gold and 18 ounces of silver. The surface ores in the same mine average 0.95 ounces of gold and 12 ounces of silver. The chief gangue minerals are quartz and calcite. Epidote and blue soda-amphibole are developed in the wall rock near the veins.

There has been very little post-mineral movement in the ores and enclosing rocks. The ores have all been deposited during a period geologically not far removed from the present. Solution and deposition of metallic minerals in the form of ore deposits has been going on in very recent times, even since the sculpturing of the present topography. Many of the smaller veins and some of the larger ones, which at the surface

* Bull. Geol. Soc. Am., XI, p. 225.

show several inches or even several feet of ore when followed away from the surface, wedge out and finally disappear in barren fractures. Deeper workings have not yet discovered any such important ore bodies as are frequently found near the surface. So far as can be seen the same conditions prevail to-day as have existed ever since ore deposition began. Therefore there is no reason to suppose that it has yet finished. The solution and redeposition of sulphides, probably going on now near the surface producing concentration, may be contemporaneous with the primary deposits of leaner sulphides at a somewhat deeper zone.

Ninety-nine per cent. of the entire mineralization of the district is said to be along joints. The other one per cent. is divided between bedding planes and contact of eruptives with other eruptives, or with the arkose series.

The chief joint-systems strike east-northeast, and the east-northeast system of veins is overwhelmingly preponderant. Mineralization has had no special preference for joints of any particular strike, but there appears to have been a slight selective tendency for joints of steep dip. The straightest veins also are richest, because the straight veins mark a fracture zone sufficiently important to control circulation. There has been no movement of importance, and the ores have not been deposited in cavities or openings, but have replaced the tonalite or andesyte country rock.

The chief veins are confined to the igneous rocks and their vicinity, and the tonalite is conspicuous for the number and richness of the veins which occur in it and near it.

Within the tonalite metallic sulphides in large and small segregations are everywhere noticeable. Scarcely a fracture crosses the rock, especially where there is water circulation, but some concentration of sulphides may be found in it. Often away from visible fractures are found bunches of pyrite closely resembling segregations.

The ores, however, are not original in the rock, but have been formed in joints and joint-zones by replacement of the country rock, which shows all the customary products of such disintegration and replacement.

The sulphide ores separate themselves by their location into two classes, recognized by the miners and called the surface ores and the deeper ores. They are:

1. Deep-seated zone, characterized by arsenopyrite, pyrite and pyrrhotite with other minerals subordinate. This underlies the surface zone and reaches to depths not yet determined.

2. Surface zone, characterized by abundance of galena, blende and chalcopyrite.

The upper sulphide zone is commercially the most important.

The occurrence and shape of the ore pockets point to deposition from downward moving waters. A favorite place for the deposition of sulphides has been at the intersection of two joints, generally a steeply-dipping and more flatly-dipping one. In many cases the ore has been deposited entirely in the bottom of the trough formed by such intersection without any considerable amount being deposited beneath the roof which the intersecting joints have formed. If the waters had been ascending the solutions would naturally have converged under this roof and would have there been precipitated more easily than in the overlying trough, but this the author has not observed. Other facts are cited to prove the theory adopted and advocated, viz., that the waters which produced the sulphide ores were distinctly descending, and that descending waters alone have produced both the primary and secondary, the leaner and the richer ores. It is stated that the oxidized zone, the intermediate sulphide zone, and part of the upper sulphide zone are all being contemporaneously precipitated at the present time.

The source of these metals is believed to be the tonalite itself, and the other eruptives; iron, lead, copper, zinc, antimony, silver and gold are known to occur in the dark-colored silicates of igneous rocks; and the magnetite of the tonalite may itself contain the other metals. The lead of the upper sulphide zone is not found in the lower sulphide zone, and is supposed to have been derived from surrounding rocks and, like all the other sulphides, to have been deposited by downward percolating waters, the different belts of minerals occurring in the order of their relative solubility.

As a practical conclusion, it is stated that the best veins in this district should be looked for in or near the tonalite, and especially along the predominant steep east-northeast joint zones.

The best ores and the largest bodies will be found near the surface, and calculations for deep mining should not be based on surface ores and shallow workings.

The pendulum of theories regarding the origin of sulphide ores seems in this paper to have swung to its extreme limit as to the work of descending waters.

For some five years past, geologists, and in particular those who have been students of the Lake Superior region, fresh from fields where descending waters have been the chief agents of deposition of some of the largest ore bodies in the world, have been applying the lessons and examples of that region and the theories of modern chemistry to the elucidation of the problems which have for centuries engaged the investigators of sulphide ores and vein mineralization.

Until very recently the suggestion of the deposition of metallic sulphides from surface waters carrying oxygen and oxidized salts would have been considered a vagary or idle theory born of unsound chemical knowledge. When, however, natural sulphides of copper and silver were found deposited on bronze coins in France and elsewhere, an explanation was necessary, and the one first advanced and generally adopted was the reducing action of carbon.

These instances, however, were believed to be entirely exceptional, and all metallic sulphides in veins were still ascribed to non-oxygenated ascending ground waters.

Physical facts noticed in the mines of Montana, Colorado and elsewhere, however, indicated very strongly the secondary origin of many sulphide ores, and their deposition by descending oxygenated waters of ordinary temperature.

Convinced finally of the possibility of producing the richer metallic sulphides by reaction between solutions of sulphates and undecomposed primary sulphides, the writer conducted some laboratory experiments in Butte during 1899 and 1900. These experiments resulted in the artificial production of chalcocite in the wet way. It was deposited upon pyrite from solutions of copper sulphate in the presence of sulphurous anhydride, one of the natural products of the oxidation of pyrite. This discovery was soon followed by the important papers of Van Hise, Weed and Emmons on the genesis of ore deposits, in which was advanced the theory of the secondary deposition

of sulphides by reaction between descending waters and primary sulphides.

Until the paper of Spurr's, however, the *original* sulphide deposits have been ascribed to warm deoxidized *ascending* solutions, and so far as the writer is informed Spurr is the first to attribute the entire mineralization of a very base series of ores to downward moving currents.

The arguments used are ingenious and forcible, and the facts seem quite largely to favor his hypothesis. The purpose of this review is not to criticise nor combat this extreme phase of the descension theory, but to call attention to it that it may be discussed by others. Still it may be said that the first objection to it which arises in the mind of the reader is its inadequacy to account for the sulphur and arsenic so abundant in the ores. The heavier metals may be derived from the ferro-magnesian silicates and from the magnetite; but where on the surface and in cold crystalline eruptives do we find sulphur and arsenic enough to produce such extensive ore-deposits?

The paper is very suggestive, and, like all of the productions of its talented author, bears the marks of originality and truly scientific methods of investigation. H. V. W.

THE SUTTON MOUNTAIN.

There is perhaps no part of the geology of North America which has suffered such vicissitudes in geological literature as the rocks which were included by the Canadian survey under the late Sir William Logan, in the "Quebec Group." Of that group the Sutton mountain rocks in the eastern townships of Quebec, have been tossed up and down in the hypothetical paleozoic scale, and in hypothetical origin, until they have just about "boxed the compass" of geological theory. This is not intended as an imputation on the geologists who have studied those rocks in the Sutton mountains, but as evidence of the difficulties of the geology, and of the imperfect methods pursued by them—both inherent in the beginnings of geological work in America. Logan, and more especially Mather, entertained extravagant notions of the efficacy of metamorphism to *change* the nature of rocks, i. e. the aggregate chemical composition. The greenstones of Sutton mountain, and of other similar ranges in the eastern townships were supposed to *have resulted* from a profound alteration of ordinary sediments. That

involved the removal of a large amount of silica and the substitution of magnesia and iron oxide throughout large masses of rock. This magnesia was found in the silicates and the iron oxide was found in the titanite and chromic iron. A slight acquaintance with the nature of basic igneous rocks would have suggested not only that these elements were indigenous, and not secondary in those rocks, but also that the structural conditions of the formations as well as the chemical combinations of these elements could have been due only to a primary origin; and that it was wholly gratuitous and impossible to entertain any such metamorphism as they assumed. To a certain extent this extreme idea of metamorphism was entertained on the south side of the international boundary. Be it said, however, that the geologists of the Vermont survey were content to designate the *kinds of rocks*, when they constructed their geological map of Vermont, (1861) without assigning to these masses any geological age other than "Azoic." Talcose schist with some serpentine and much more gneiss and some granite, was said to compose the Green mountains of Vermont, these being in the direct southward continuation of Sutton mountain.

T. Sterry Hunt first questioned the post-Potsdam age and the metamorphic origin of the Sutton mountain rocks, (1871) and Selwyn considered them as probably of the same age as the copper-bearing rocks of the region of lake Superior, and of like origin (1877). Ebenezer Emmons consistently and uniformly maintained the greater age of the Green mountains, but his views, as well as those of Hunt, were overborne and out-ruled by officialism and its partisans.

These remarks are prompted by the article of Prof. J. A. Dresser in the July number of the American Journal of Science (*A Petrographical Contribution to the Geology of the Eastern Townships of the Province of Quebec*, p. 43) by whom the Sutton mountain is regarded not only as of igneous origin, but of pre-Cambrian age. According to his descriptions the rocks of the region of Sutton mountain are greenstones, but little accompanied by gneiss, or by quartz porphyry. They lie below certain mica schists which contain fragments from them, and are much older than the sedimentary portions of the Quebec group. They appear hence to be a part of the Archean.

The tendency therefore has been downward, and since they are now apparently assigned to the Archean, it may be that

ultimately they will be found to be at the very bottom of the Archean. They would then be in the same position as the Kawishiwin, of Minnesota, and might be considered the present representative of the original igneous crust of the earth; the two igneous ranges which are represented further east on the map of Mr. Dresser corresponding to two other similar ranges which have been described in Minnesota south from the oldest greenstone range. There is at least a suggestive parallelism which can be expressed thus:

Minnesota.

Giant's range (at Twin peaks).
 Mesabi range (at Gabbro lake).
 Sawteeth range.

Eastern Townships.

Sutton mountain.
 Stoke mountain.
 Lake Megantic.

N. H. W.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

United States Geological Survey, Twenty-first Annual Report to the Secretary of the Interior, 1899-1900. CHARLES D. WALCOTT, Director. Part III. General Geology, Ore and Phosphate Deposits, Philippines. Pages 644, with 68 plates, and 104 figures in the text. Washington, 1901.

The first paper of this volume is by Prof. William H. Hobbs, on "The Newark System of the Pomperaug Valley, Connecticut," in 160 pages, illustrated by 17 plates and 59 figures. This area of the Newark series, though only about ten miles long and two miles wide, is exceedingly interesting on account of its development of nearly vertical joint planes and systems of faults. It had been fruitfully studied and described by Percival and Davis. For the more detailed studies noted in this report it was partly mapped on the large scale of four inches to a mile, with exact locations of nearly every rock outcrop. Specimens of fossil wood from the lowest member of the series are determined by F. H. Knowlton as *Araucarioxylon virginianum*, before described and named by him from Newark areas in Virginia and North Carolina.

Thomas A. Jaggar, Jr., contributes the second paper, "The Laccoliths of the Black Hills," in pages 163-303, with plates 18-47, and figures 60-102. His summary of field observations and geologic inferences is in part as follows: "Igneous intrusions of rhyolite and phonolite porphyries accompanied or immediately followed a great movement of uplift in the area now occupied by the Black Hills. This uplift arched the horizontal strata of the plains into an elongate dome; schists be-

neath, with nearly vertical bedding and lamination, moved up by faulting and slipping, frequently on planes of schistosity:.....Erosion has left laccoliths covered, partially uncovered, and deeply dissected, and in places has removed them entirely or left only scattered remnants. Conduit, basement contact, wedge, flank, crest—all parts of the laccolith are exposed, in plan and section in different places in the Black Hills. The evidence quoted points to Eocene time as the age of intrusion. There were several thousand feet of strata above the laccoliths, and the soft Cretaceous shales absorbed laterally the doming produced by individual intrusive masses.....Intrusion is not conceived to have been in any sense a cause of the greater uplift, but an effect. The intrusions were a small incident in a great movement of elevation. The greater uplift probably took place after the close of the Laramie, along with similar movements in the Big Horn Range and the Rocky Mountains. Whatever their cause these movements were colossal and involved a considerable section of the earth's crust.....The fractures reached downward to a zone where molten rock was under pressure. The liquid shot upward into every ramification of the fracture system." In the last chapter of this paper, Ernest Howe describes a series of very instructive laboratory experiments illustrating intrusion and erosion, "imitating as far as possible the processes involved in the formation of laccoliths and the resulting deformation of the invaded beds."

Prof. C. R. Van Hise, in the third paper, treats of "The iron Ore Deposits of the Lake Superior Region," noticed in editorial comment by U. S. Grant in the last January *AMERICAN GEOLOGIST*. Among the maps illustrating this paper are three of large size, folded, on the scale of a mile to an inch, showing the geology and contour of parts of the Menominee, Vermilion and Mesabi iron-mining districts.

The next two papers, by Charles Willard Hayes, describe "The Arkansas Bauxite Deposits," and "Tennessee White Phosphate." Bauxite, recently in great demand for the production of aluminum, has been known to occur abundantly in Arkansas since its deposits there were first described in 1891 by Dr. J. C. Branner, the state geologist. Owing to the approaching exhaustion of its only other important deposits known in the United States, in a district of Georgia and Alabama, extensive mining of the bauxite in Arkansas will probably begin soon. It is estimated that about six million tons are in view in outcrops, and that deep mining will supply more than forty million tons. "About 2 tons of bauxite are required for the production of 1 ton of alumina. The value of the bauxite at the mine is about \$3 per ton, whereas the value of the alumina is \$60 per ton."

The white phosphate deposits of Perry county, Tennessee, as shown by Mr. Hayes, were formed in caverns of Silurian limestone strata, being thus essentially pockets, though occasionally of large extent. The amount in any locality can be estimated only after a systematic exploitation. Some of these deposits are now being actively developed by mining.

Dr. George F. Becker presents the final paper of this volume, a "Report of the geology of the Philippine Islands," of which an advance

copy was reviewed a year ago in the AMERICAN GEOLOGIST for August, 1901. This paper occupies pages 487-614, and is followed by a translation, in eleven pages, from K. Martin, "Concerning Tertiary Fossils in the Philippines." w. u.

On some Fossils from the Islands of Formosa and Riu-Kiu (Loo Choo). R. B. NEWTON and R. HOLLAND. (Jour. Coll. Sci., Imp. University. Tokyo, vol. 17, Article 6. 1902. pp. 23, 4 plates).

We had occasion a few months ago to review, in the GEOLOGIST,* the late contribution by Mr. S. Yoshiwara to the geology of Riukiu Curve, a series of islands largely volcanic extending northward from Formosa. It appears that the fossils collected, or some of them at least, were sent by professor Koto to England. They have been examined and reported on by Messrs. Newton and Holland. They show no older formations than the Miocene. It remains yet, therefore, to future geological examination to supply the paleontologic data from which the paleozoic age of the basic rocks of the Riukiu curve can be affirmed. N. H. W.

The Eparchean interval. A. C. LAWSON. (Bull. Dept. Geol., Univ. Cal., vol. 3. pp. 51-62, May, 1902.)

It was a happy thought which led to the emphasizing of this non-conformity by the term *eparchean*. It is as worthy of special name as the loessian inter-glacial epochs, and is much more widespread. It is an interval which now is unanimously recognized by those who have studied the Archean attentively. That the Archean age closed with the Archean rocks folded and compressed to verticality, or approximate verticality, that it was followed by a series of sediments whose strata are horizontal, or approximately horizontal, are truths which now no one questions. The land interval which occurred between the dates of formation of discordant marine formations was probably long and eventful. We may assume that much land existed during that interval, but in some cases there is but slight evidence of coarse detrital accumulation. This interval was followed apparently, by quick submergence, at least in some parts of the lake Superior region, and upon it were then piled up the Paleozoic sediments which have never been subjected to the profound folding and metamorphism that are so evident in the Archean. Hence a great lithologic and stratigraphic chasm exists at this horizon, and this is attended also by a profound biotic change. No organic remains have been found below this interval, but they have been found in the nearly horizontal strata which succeeded the non-conformity.

We sympathize with Dr. Lawson in his castigation of the term Algonkian and of those who introduced it into American geology. It has been a source of confusion and misinterpretation. It has been generally supposed that it covered about the same interval as the term Huronian, but Dr. Lawson shows that it replaces Archean. It has, indeed, had so many and so varied definitions and stratigraphic limitations, sometimes theoretical and sometimes concrete as applied in

* April, 1902, vol. xxix, p. 253.

the lake Superior region, that it is doubtful if it is now possible to frame a definition which would not require numerous local modifications and special adaptations. It is because it is in the literature of the United States Geological survey, and in its vagueness was made to take the place of formations that had some definiteness that it has arisen as a formidable obstacle to the foreign geologist who attempts to read American geological reports.

N. H. W.

Geological Survey of New Jersey, Annual Report of the State Geologist for the year 1901. HENRY B. KÜMMEL, Acting State Geologist. Pages xxviii and 178, with 7 plates, and a folded map of the geology of the Green Pond Mountain Region in Morris and Passaic Counties. Trenton, N. J., 1902.

The administrative report, in 16 pages, by Mr. Kümmel, is followed by four special reports: I. The Rocks of the Green Pond Mountain Region, by Mr. Kümmel and Stuart Weller; II. Artesian Wells, by Lewis Woolman; III. Chlorine in Natural Waters, by William S. Myers; and IV. The Mining Industry, by Mr. Kümmel. It is announced that the final report of Prof R. D. Salisbury on the Surface formations of the northern part of the state, including the glacial drift area, is expected to be published during the present year. Another very important report, on the clay industries, is in process of preparation by Mr. Kümmel and Dr. Heinrich Ries. The value of the clays mined and sold in 1900 was \$467,881, or 25.4 per cent. of the whole for the country; and the output of clay products amounted to \$10,928,423, or 11.36 per cent. of all for the country, the rank of New Jersey being the third in the United States.

W. U.

The Story of the Prairies; or the Landscape Geology of North Dakota.

By DANIEL E. WILLARD, Professor of Natural Sciences, State Normal School, Mayville, N. D. Pages 256, with 83 photogravures, drawings, and maps, including a map of the state showing its marginal moraines and glacial lakes. Published by the author, 1902. Price, \$1.75, with 15 cents added for postage.

This admirable description of the physical geography and the geology of North Dakota is designed for use in the public schools, and for its citizens who are interested in its geologic history and resources. The drift sheet, its parallel and interlocking belts of moraine hills, the flat beds and bordering beaches of the glacial lakes Agassiz, Souris, Sargent, and Dakota, the Cretaceous plains and Bad Lands, deposits of lignite coal, artesian wells, etc., are so described as to stimulate the readers or pupils to observe and reason for themselves concerning the geologic origin and history of these great northwestern prairies and plains.

W. U.

An Introduction to Physical Geography. By G. K. GILBERT and A. P. BRIGHAM. pp. 380, New York. D. Appleton and Company, June, 1902.

This excellent treatise was printed so lately that it has an account of the volcanic eruptions in May last, in the West Indies, near the middle of the book. The authors are well known geologists, and they have

not failed to compass the field in a most entertaining and yet elementary, style. The work is intended for the "earlier stages of the high-school course," and it is a masterpiece in the accomplishment of that design. Most of the picture illustrations, as well as text descriptions, are from natural scenes in the United States. Principles are drawn from concrete cases. Indeed, as the authors state, "the treatment, so far as possible is concrete." The illustrations are new and telling. In a general but rather thorough, examination of the book we have been impressed with the clearness and yet conciseness of its simple sentences. We have noticed but few vague or incorrect statements, and these imply slight errors in the understanding of the facts. On page 149 this statement is made: "The Mississippi was thus, as we have seen, forced out of the old open valley, at Minneapolis, and is gradually reducing the grade of its new course by cutting the gorge that runs down to St. Paul." It should have read *down to Fort Snelling*, since the gorge from Fort Snelling to St. Paul is much older than the gorge which the river is now cutting. Also on page 67 is the statement that the upper Mississippi "flows in a valley between rocky but often well-separated bluffs. At Minneapolis it enters a short gorge," etc. As a matter of fact, the upper Mississippi, above Minneapolis never flows in a rocky, bluff-bound gorge, and it but rarely encounters the rock in a course of several hundred miles between its source and Minneapolis, running wholly on the drift deposits. These slight errors of fact do not impair the force of the truths inculcated. It is, further, a question whether the term "glacial lakes" should be applied to the lakelets filling the hollows in the morainic belts, since it is so widely used to designate those extinct lakes which filled the valleys during the prevalence of the Glacial epoch.

N. H. W.

Western Interior Coal Field; by H. FOSTER BAIN. (U. S. Geol. Sur., 22nd Ann. Rept., pt. iii, pp. 331-366, 1902.)

An admirable summary of the commercial aspects of the coals from the fields of Iowa, Missouri and Kansas is that given by Dr. Bain in the 30 pages of the 22nd annual report of the U. S. geological survey. After briefly referring to the geological distribution, the stratigraphy and the structure, the number and extent of the workable beds are discussed. "In the Western Interior field the coal is very irregularly developed along the various coal horizons. Indeed it has so far proved impossible to make a general section showing even the coal horizons which would be of more than local value. This patchy distribution of the coal is not the result of later faulting or other dynamic phenomena, but is due to the conditions under which the coal was accumulated. The bulk of the coal mined, 80 to 90 per cent., is taken from the Cherokee shales. From 10 to 18 per cent. is from the other divisions of the Lower Coal Measures. The remainder is from the Upper Coal Measures. The coal beds of the Cherokee shales are much more irregular than those found higher in the series. They are also much thicker. They, however, thicken and thin very rapidly, varying from nothing to 7 feet in a horizontal distance of a few feet. The usual variation is from 18 inches to 6 feet. The thicker workable beds lie in basins or

troughs of very irregular outline. The coal varies a little in elevation, differences of 20 to 30 feet being common, and as much as 60 feet of local dip being observed in a single mine. Usually the coal thins to the rise, and it seems that the irregularities are a result of original irregularities of the bottom over which the coal accumulated."

As to character it is stated that the coals are mainly adapted for domestic and steaming purposes, and practically the entire output is devoted to these purposes. A table of analyses of some of the most important coals is given. Tables are also given of boiler tests of the Iowa coals, evaporation tests of Missouri coals and tests of railway locomotive runs.

The methods are concisely described. The labor question is of special interest. "The operators of this field are fortunate in the character and conditions of their labor. An unusually large percentage of the men working in the mines are English-speaking, either Americans or English, Welsh or Irish. In certain camps negro labor has been introduced as a result of strikes, but on the whole such camps are few. Of recent years Italians and Slavs have been coming into the region, and in certain districts, notably the Cherokee coal field of Kansas and Missouri, and the Centreville or Appanoose district of Iowa and Missouri, they form a majority of the workmen. The Anglo-Saxons are the best miners. They have a better comprehension of the work to be done, and are quicker and more intelligent in the handling of machinery. Indeed, practically all the machinery about the mines is handled by them, and almost all the bosses are chosen from their ranks."

Detailed cost of mining coal in the various districts presents some unusually instructive phases. The account of the location and character of the markets contains much new material.

The stratigraphy is perhaps too briefly considered. And it is noted that by some oversight in both text and maps the Lower Coal Measures is referred to the Missourian series, and the Upper Coal Measures to the Des Moines series.

C. R. K.

MONTHLY AUTHOR'S CATALOGUE

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CORRESPONDENCE.

RICHARD BURTON ROWE. Richard Burton Rowe died in Los Angeles, California, on May 26, aged 30 years. His death was due to tuberculosis, against which he had bravely struggled for nearly two years. His early demise will be regretted by all geologists who were acquainted with him and his promising work.

Dr. Rowe was born in Clarksville, Albany Co., New York, May 3, 1872, and received his early education mainly at Clarksville and in the

Albany High School. He entered Union College in 1892, graduating with the degree of Ph. B. in 1896. At his graduation he received special honors in geology, the subject of his thesis being a study of the geology and paleontology of the Helderbergs near the eastern base of which his home was located. The following year he remained at Union as an assistant in geology and in the summer of 1897 he began work with the Maryland Geological Survey on the Paleozoic formations of the western part of the state. In the autumn, as a graduate student in geology, he entered Johns Hopkins University where he remained for three years, continuing on the state survey during the summer vacations. He held a scholarship in geology during the University year of 1898-99 and the fellowship in geology for 1899-1900, receiving his Ph. D. degree in 1900.

Dr. Rowe's work on the Paleozoic formations of western Maryland was valuable and led to the effort to correlate them more closely with the standard formations of the New York column. He described the Eodevonian formations of the state for the Maryland survey, identified many of the fossils, describing a number of new species. This work will appear in the Devonian volume of the Maryland survey under the title: *The Paleodevonian formations of Maryland; a study of their stratigraphy and faunas*; one of America's foremost Paleozoic paleontologists states that his descriptions of fossils in this report show a high order of ability.

Soon after receiving his doctorate he passed the Civil Service examination and was appointed an assistant geologist on the U. S. Geological Survey in the division of Dr. C. W. Hayes. Before reporting for field duty, however, he was attacked with malarial fever and later examination revealed the beginning of tuberculosis. In November, 1900, Dr. Rowe was assigned by the U. S. Geological Survey to duty in southern Nevada, and, under the invigorating influence of that climate, partly regained his health. While on a geological camping expedition during the past autumn and winter he overexerted himself and from these effects he never recovered.

Dr. Rowe was a modest man of agreeable manners and an enjoyable companion. The writer has spent many days with him in the field, finding him an earnest worker, an accurate observer, and an efficient assistant. It is specially sad that his life has been brought to such an early close when he was, apparently, just entering upon a most promising career.

He had published the "Stratigraphic geology of the eastern Helderbergs" (17th ann. rept., state geologist. [N. Y.], pp. 342-355, pl. 5-10.) and "Map of Allegany county showing the geological formations and agricultural soils," in association with Dr. C. C. O'Harra (Maryland Geological Survey, Physical Atlas of Maryland, 1900, 3 sheets.)

During the past two years he had made extensive paleontological collections from the Mesozoic and Paleozoic formations of southern Nevada and California. At the time of his death he was engaged in the preparation of a report on the geology of this region.

CHARLES S. PROSSER.

PERSONAL AND SCIENTIFIC NEWS.

DR. T. C. HOPKINS, Professor of Geology at Syracuse University, is spending the summer in geological work in Ontario.

THE DEGREE OF DOCTOR OF LAWS WAS CONFERRED ON DR. JOHN M. CLARKE of Albany, one of the editors of the *American Geologist*, by Amherst college at the late Commencement.

MR. MORGAN (J. PIERPONT) has added a collection of gems and precious stones to the mineralogical collection in the Museum d'Histoire Naturelle at Paris, the value of which is said to be ten thousand dollars.

RIGNON DE LA VIEJO, a volcano about 60 miles south of lake Nicaragua, in Costa Rica, was in eruption June 28. There is a large mountain creek flowing at its base. It would have to have a long surface fissure to get enough water for a grand explosion unless through subterranean channels that might connect its caverns with lake Nicaragua or with the Pacific.

J. Crawford.

THE NINTH SESSION OF THE INTERNATIONAL CONGRESS OF GEOLOGISTS is duly announced by circular from the "Committee of Organization." It will occur at Vienna, Austria, 20 to 27 August, 1903. The president of the executive committee is E. Tietze, and the general secretary is C. Diener. There will be a series of grand excursions both before and after the session, and smaller excursions in the environs of Vienna during the session.

NOT UNDERSTANDING THE RELATIVE MINUTENESS of the speck of cosmic dust on which we reside, and notwithstanding the relative incompetency of the mind to discover our exact relations to the rest of the universe, it has yet been possible to measure that minuteness, and to determine that incompetency. These, in brief, are the elements of positive knowledge at which we have arrived through the long course of unconscious, or only half-conscious, experience of mankind. All lines of investigation converge towards or diverge from these elements.

R. S. WOODWARD.

THE UNITED STATES OF TEXAS MINERAL SURVEY which was organized a year ago, has already issued two bulletins, the first on "Petroleum" and the second on "Sulphur, Oil and Quick-silver in Trans Pecos Texas." The latter, as stated by Dr. Wm. B. Phillips, the Director, "deals with the results of the examination of certain public lands in the counties of Brewster, El Paso, Jeff Davis, Presidio, and Reeves. It contains two reports on the sulphur deposits of El Paso county, showing that they are well worth attention and that they could supply large quantities of sulphur to commerce. There is also a description of the quick-silver ores in Brewster county, show-

ing the extent of the field, the value of the product, and the possibilities of further development." A third bulletin on the "Coals, Lignites and Asphalt Rocks of Texas" is now in the hands of the printer and will probably soon be ready for distribution.

Mr. Benj. F. Hill, the assistant geologist, has been for some time actively engaged in field work in the quick silver region of Brewster county, the results of which will appear in the form of a third bulletin to be issued about the first of September. The Survey, in cooperation with the U. S. Geological Survey, is now preparing topographic maps of this area, the work being under the supervision of Mr. Arthur Stiles, Topographer of the U. S. G. S.

HARVARD UNIVERSITY.—Dr. A. W. G. Wilson has been appointed demonstrator in geology at McGill University.

Professor W. H. Niles, of the Mass. Institute of Technology, has resigned.

The glacial work of the New York state survey is directed this season chiefly toward working out the Champlain shore lines on the north side of the Adirondacks.

Professor W. M. Davis has conducted a party in another trip to the Grand Cañon, to study neglected problems connected with its history. The work closes about August 15th.

Dr. J. E. Woodman has been appointed assistant professor of geology and mineralogy at Dalhousie University, Halifax, Nova Scotia. In addition to work in the department of geology, it is planned to develop a school of mining engineering.

Mr. L. La Forge is to be an Austin teaching fellow in geology for the next college year, continuing with Dr. T. A. Jaggar, Jr., work upon the Boston folio of the U. S. geological atlas. He has worked during part of this season upon the rocks in the vicinity of the Hibernia mine, in New Jersey, long studied by professor J. E. Wolff. The latter is now engaged exclusively in the Green mountains of Vermont.

COLUMBIA UNIV. GEOLOG. DEPARTMENT. Prof. J. F. Kemp is spending some weeks in Wyoming and Utah. Amongst his other work he will spend several days in the classic Leucite Hills region.

Dr. A. A. Julien is continuing his study of the Cape Cod sands.

Mr. D. W. Johnson, fellow in geology, is spending the summer in some Jurassic and Triassic fields in New Mexico and Arizona.

Mr. H. W. Shimer, assistant in paleontology, is engaged in a study of the lower Devonian rocks of Port Jervis, N. Y., and vicinity.

Prof. A. W. Grabau is at present engaged in working up Becraft Mt., near Hudson, N. Y., structurally and stratigraphically, for the New York state survey.

Mr. G. S. Finlay, assistant in geology, is spending most of the summer on the chemistry and petrography of some rocks from Mexico, the areal work on which he did last winter.

Mr. Fred Moffit, fellow elect in geology, has spent the last four summers in assisting professor T. Nelson Dale in the slate belt of New York and Vermont for the U. S. G. survey. He will spend four or five weeks in finishing the work in Vermont, and the remainder of the summer at Slatington, Pa. Here he will be engaged with Prof. Dale in mapping the slate belt for the U. S. G. survey.

PROF. ANGELO HEILPRIN, president of the Philadelphia Geographical Society, has returned to Fort de France from his explorations of the crater on the summit of Mont Pelee. He has settled some important points. The location of the new crater has been accurately determined; it is known that there has been no overflow of molten matter from the lip of the crater; there has been no subsidence of the mountain, and the height of Mont Pelee is unchanged. There has been no cataclysm and no topographical alteration of the country. The period of violent eruptions has probably ended, although the volcano may continue to be somewhat active for a long time to come. "As we stood on the edge of the crater," says the professor, "a sublime spectacle began. I now have some conception of what is going on inside the earth, and have been a spectator of nature's secret interior work. We were assailed with noise. Far below there was a hissing of steam like that of a thousand locomotives, as well as violent detonations. The eruption of Mont Pelee of May 8 was unique in that it resulted in the greatest destruction of life and property ever known by direct agency of a volcano. The phenomenon of explosion of flaming gases is probably new, but a careful study of observations is necessary before an opinion can be reached. The electrical phenomena are also new. They probably did not play the chief role in the destruction of St. Pierre, but were developed by and aided the other force. I have specimens which show the effects of the bolts of lightning. The latter were small and intense and penetrated within the houses of the city. For rapidity of action and for lives lost Mont Pelee holds the record among volcanoes."

GEOLOGICAL EXCURSION IN THE VICINITY OF PITTSBURG, PA. From June 23 to 30 a number of geologists participated in an excursion in connection with the Pittsburg meeting of the American Association for the Advancement of Science and the Geological Society of America. The excursion was under the leadership of Dr. I. C. White, of Morgantown, W. Va., whose extensive acquaintance with the coal, oil and gas fields of western Pennsylvania and West Virginia, together with his genial manner, made him a most excellent head of such an excursion.

He was assisted in many ways by Mr. J. R. Macfarlane, of Pittsburg, and Mr. R. R. Hice of Beaver, Pa.

In the course of the week devoted to the excursion many points of interest in stratigraphic, economic, glacial and physiographic geology were seen. The main features of the phenomena observed clustered about two points. The first was the high level terraces, covered by gravels, of the Monongahela, Alleghany and other streams, and the connection of these terraces with a preglacial river flowing northward into the Lake Erie basin by way of the present Beaver valley. The second was the detailed stratigraphy of the Permo-Carboniferous rocks and the great distance over which some of the thin members of this column could be identified.

Those participating in the excursion were as follows: Miss F. Bascom, Bryn Mawr, Pa.; S. B. Brown, Morgantown, W. Va.; A. S. Coggeshall, Pittsburg; L. S. Coggeshall, Pittsburg; D. E. Crane, Sewickley, Pa.; A. R. Crook, Evanston, Ill.; C. R. Eastman, Cambridge, Mass.; B. K. Emerson, Amherst, Mass.; H. L. Fairchild, Rochester, N. Y.; A. W. Grabau, New York City; U. S. Grant, Evanston, Ill.; C. M. Hamilton, Pittsburg; J. B. Hatcher, Pittsburg; R. R. Hice, Beaver, Pa.; J. R. Macfarlane, Pittsburg; G. C. Martin, Baltimore; Miss L. K. Miller, Groton, Mass.; Miss Ida H. Ogilvie, New York City; F. H. Oliphant, Oil City, Pa.; A. E. Ortman, Princeton, N. J.; F. B. Peck, Easton, Pa.; Sidney Prentice, Pittsburg; C. S. Prosser, Columbus, O.; H. W. Shimer, New York City; A. E. Turner, Waynesburg, Pa.; I. C. White, Morgantown, W. Va.; J. C. Williams, Ridgeway, Pa.

The following geological papers were read at the Pittsburg meetings:

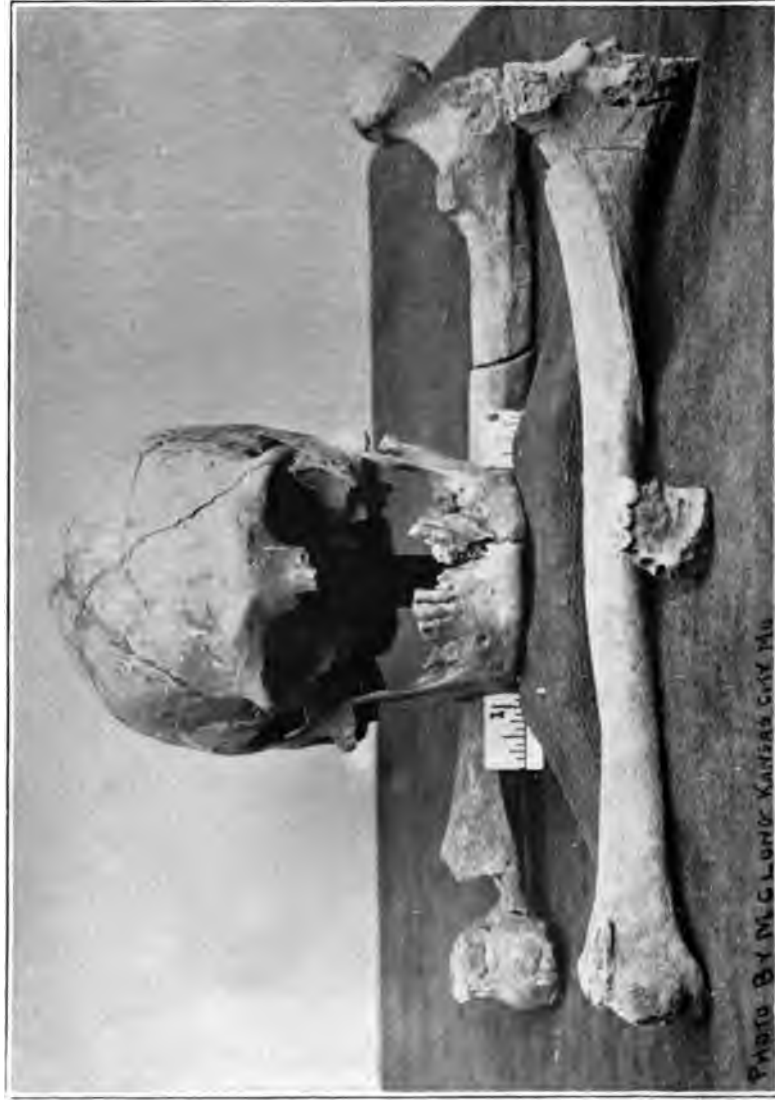
1. "Geology of the Pittsburg Region." (45.)
I. C. White.
2. "Lower Carboniferous of the Appalachian Basin." (title.)
J. J. Stevenson.
3. "A New Meteoric Iron from Algona, Wis." (20 m.)
(Lantern.)
W. H. Hobbs.
4. "Meteorites of Northwestern Kansas." (20 m.)
(Lantern Views.) Oliver C. Farrington.
5. "The Mohokea Caldera on Hawaii." (10 m.) (Lantern Views.)
C. H. Hitchcock.
6. "Ellipsoidal Structure in Pre-Cambrian Basic and Intermediate Rocks of Lake Superior Region." (20
J. Morgan Clements.
7. "Vermilion District of Minnesota." (20 m.) (Lantern Views.)
J. Morgan Clements.
8. "The Pacific Mountain System in British Columbia and Alaska.
Arthur C. Spencer.

9. "Development of the Southeastern Missouri Low lands."
(10 m.) C. F. Marbut.
10. The International Geographic Congress of 1904 under the Auspices of the National Geographic Society." (10 m.) (title.)
Gilbert H. Grosvenor.
11. "Possible Effects of the Glacial Period Upon the Land Levels of Central Asia." (10 m.) G. Frederick Wright.
12. "Recent Geology of the Jordan Valley." (14 m.)
G. Frederick Wright.
13. "History of the Discoveries and Discussions Concerning the Glacial Terraces in the Upper Ohio and Its Tributaries."
(20m.) G. Frederick Wright.
14. "Submerged Valleys in Sandusky Bay." (10 m.)
E. L. Moseley.
15. "Some Geological Notes in Honduras, Central America." (15m.)
(title.) J. Francis Patch Le Baron.
16. "Great Canon of the Euphrates River." (20 m.)
Ellsworth Huntington.
17. "Systematic Geography." (20 m.) W. M. Davis.
18. "Some Topographic Features in the Southern Appalachians."
(15 m.) (Lantern Views.) J. A. Holmes.
19. "The Petrographic Province of Neponset Valley, Boston, Massachusetts." (10 m.) (title.) F. Bascom.
20. "The Occurrence of Liquid Petroleum Hermetically Enclosed with Quartz Crystals, from Alabama." (5 m.) F. L. Stewart.
21. "Restoration of *Embolophorus dolloivianus*." (10 m.) (title.)
E. C. Case.
22. "Synopsis of the Missourian and Permo-Carboniferous Fish Faunas of Kansas and Nebraska." (10 m.)
C. R. Eastman and E. H. Barbour.
23. "Phylogeny of the Cestacient Group of Sharks." (10 m.)
C. R. Eastman.
24. "On a Complete Skeleton of a New Cretaceous Plesiosaur, Illustrated by Photographs from Mounted Skeletons." (10 m.)
S. W. Williston.
25. "The Bacubirito Meteorite." (20 m.) H. A. Ward.
26. "Palaeontological Notes." (title.)
(a) Notes on Gastropods,
(b) *Spirifer mucronatus* and its Derivatives." (20 m.)
(Lantern Views.) A. W. Grabau.

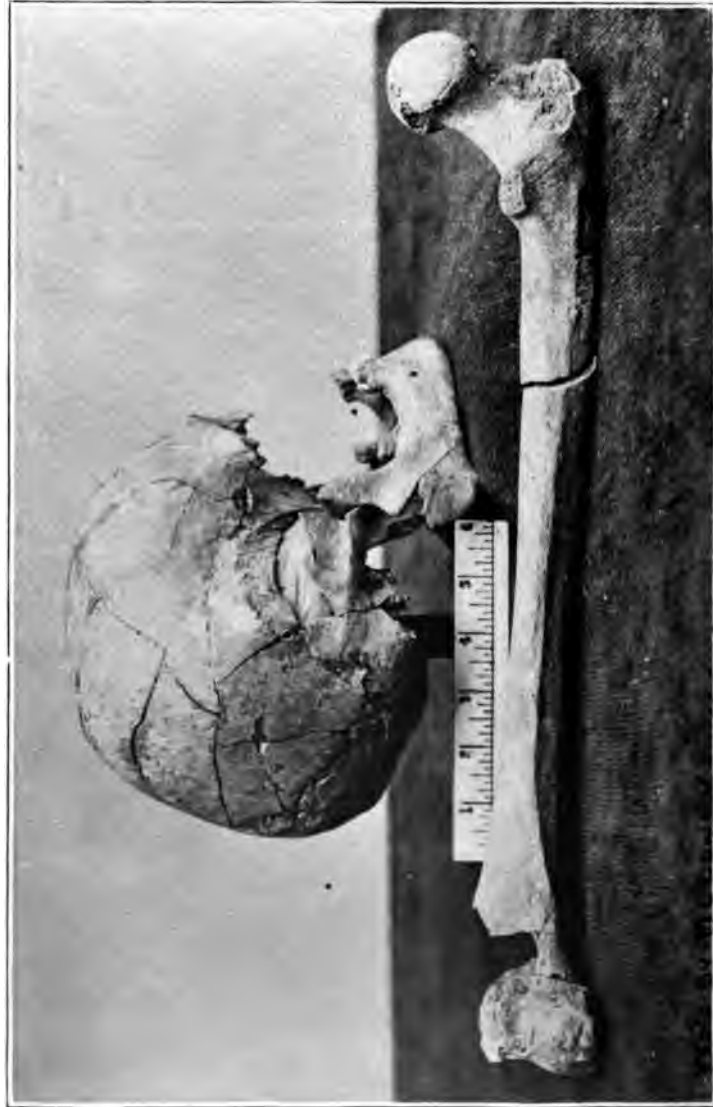
The following papers were read under the auspices of the National Geographical Society.

27. Scientific Results of the Recent Eruptions in the West Indies.
R. T. Hill.
28. The Magnetic Disturbances during the Time of the Recent Volcanic Eruptions in Martinique.
L. A. Bauer.
29. Atmospheric Phenomena in connection with the Recent Eruptions in the West Indies.
A. J. Henry. (Read by G. H. Grosvenor.)

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FRONT VIEW OF THE LANSING SKULL, WITH THE THIGH BONES.



PROFILE OF THE LANSING SKULL.



miles northwest from Kansas City. His sons, Michael T. and Joseph F. Concannon, found the skull and most of the bones in their digging near the end of the tunnel, 69 to 71 feet from its entrance, 2 to 6 feet from its east side, and $1\frac{1}{2}$ to 2 feet above its floor. The bones were disjointed, and were partly broken, decayed, and irregularly strown about; but mainly they were huddled together in one place. The ribs and vertebrae were mostly decayed, so that they could not be preserved. Half of the broken lower jaw had been previously discovered, ten feet nearer the entrance and about one foot lower, that is, only a foot above the floor of the tunnel; and near that spot a phalangeal bone was found embedded in the wall of the tunnel by one of our party. The other half of the lower jaw, matching that found before, was with the chief parts of the skeleton. No bones besides these of a single human skeleton were found in the entire excavation of the tunnel; nor were any implements, artificially chipped stone flakes, or other articles of human workmanship discovered. The illustrations in Plates II and III are kindly contributed by Mr. M. C. Long, to accompany this paper.

Mr. Concannon and his sons supplied lights for our examination of the section displayed in the tunnel; and they kindly showed us where the bones were encountered, with detailed relation of the circumstances of their discovery. At first they had not suspected its scientific importance, and nearly a month passed before the first newspaper mention of it appeared in the *Kansas City Star*. Within a few days later the locality was examined by M. C. Long and Edwin Butts, of Kansas City, Mo., the former being curator of the City Public Museum, and the latter civil engineer of the Metropolitan Street Railway, by whom the skeleton was obtained with the design of placing it in that museum. The skull was found entire, but had afterward been accidentally broken into many pieces, which Mr. Long fitted together, depositing it in the museum; but the other bones, including both parts of the lower jaw, were at the time of our visit in the possession of Mr. Butts, at whose home they were examined by all our party. From where the skeleton was found, the overlying loess deposit has a thickness of 20 feet, as determined by Mr. Butts, to the surface of the ground above. Measurements of the tunnel were also

made by him, showing it to be 72 feet long, about 10 feet wide, and about $7\frac{1}{2}$ feet high. Its walls are vertical to the height of about six feet, above which the top is flatly arched, with no other support than is supplied by the well known coherent texture of the loess formation in which this upper part of the tunnel is dug. Resulting from their visit, a second article in the *Kansas City Star*, of March 23, written by Mr. Sutermeister, announced the provisional reference of the skeleton to a part of the Glacial period estimated as 35,000 years ago.

Upper Carboniferous limestone, determined from the abundant fossils collected by Mr. Hare in the region about Kansas City, outcrops at the site of the tunnel, and at much higher elevations close southeast, and somewhat farther away to the south, west, and northwest; but mainly it is covered and concealed by the extensive and very thick valley drift deposit of loess. The limestone, in a compact bed several feet thick, forms the floor of the tunnel, rising nearly two feet along its extent of 72 feet south-southeast into the bluff. Fragments of limestone and shale, with much earthy debris, rested on this floor along all the area of the tunnel, having a variable thickness of 2 to 4 feet, but mainly about $2\frac{1}{2}$ feet, and being thickest and most stony, as seen in the section, at the east wall of the tunnel. In the debris which thus formed the lower third of the excavation, fragments of the limestone, and of its associated thin shaly layers, are common up to 6 inches long, and several masses 1 to 3 feet long were encountered. One measuring 12 by 20 inches is imbedded in the head of the tunnel, only two or three feet from the site of the skeleton, and at a little greater height. The skeleton lay in the upper foot of the debris, or perhaps in a hollow of its surface; but the half of the lower jaw found separate, a foot lower, was certainly imbedded in the stony debris about a foot below its top where it is overlain by the loess. The Carboniferous limestone, from which its fragments in the debris appear to have been derived, outcrops within 50 feet southeast of Mr. Concanon's house, or only about 150 feet southeast of the tunnel, having there a height of 50 or 60 feet above the tunnel floor. Thence the rock outcrop gradually rises southeastward as a spur ridge, attaining within the distance of an eighth of a mile a height of fully 125 feet above the floor of the tunnel, or

about 150 feet above the ordinary level of the Missouri river; and the overlying loess rises onward to a height of 200 feet, or more, above the river, within another eighth of a mile, reaching there the general level of the top of the river bluffs and adjoining uplands.

According to the surveys of the Missouri River Commission, the extreme low and high stages of the river here during the period from 1873 to 1885 were respectively 735 and 760 feet above the sea level, the vertical range being 25 feet.* The extreme high water was in 1881, being the highest within the thirty-five years since Mr. Concannon settled here; but it was exceeded, probably six or seven feet, by the high water of 1844, of which a record was made at Kansas City. The skeleton was at a height of 11 to 12 feet above the high water of 1881, or 772 feet, nearly, above the sea; and the house is about 35 feet higher, with the limestone outcrop extending from near it up to about 900 feet above the sea, while the higher crests of the loess near by are at 950 feet, estimated approximately.

The coarse debris in the lower part of the tunnel contained, so far as we could observe, no glacial drift pebbles or stones of foreign origin, though they are frequent in the thin glacial drift which overlies the rock surfaces near. Many of these drift stones and boulders are of the red Sioux quartzite, which outcrops 300 to 350 miles northward, in southwestern Minnesota, the northwest corner of Iowa, and the southeast part of South Dakota. It occurs in this Kansan drift mostly in small fragments, but often one to two feet in diameter, and occasionally even measuring five feet, or more, and weighing several tons. The southern boundary of the glacial drift, marking the limit of the continental ice-sheet in its extreme extension during the Kansan stage of the Glacial period, is at a line passing from east to west, as mapped by Chamberlin and McGee, about 12 or 15 miles south of the Kansas (commonly called the Kaw) river, and 25 or 30 miles south of Lansing.†

Above the debris, which exhibits no marks of water assorting and deposition, the section, very clearly seen in each side

*U. S. Geol. Survey, Bulletin 72, 1891, p. 166.

†U. S. Geol. Survey, Seventh Annual Report, for 1885-86, pl. viii (map of the drift area and glacial striae of the United States.)

and at the end of the tunnel, consists for its upper two-thirds of the very fine siliceous and calcareous yellowish gray silt called loess, containing no rock fragments nor layers of gravel and sand, excepting a thin layer of fine gravel, with limestone and shale pebbles up to a half inch in diameter, which was noted by Mr. Butts near the roof of the tunnel, having a thickness of about four inches and an observed extent of some 30 feet. Soon after the skeleton was imbedded in the stony debris, or lay exposed on its surface, the geologic conditions that appear to have long prevailed were somewhat suddenly changed, and there ensued a more rapid deposition of the very fine water-laid loess, deeply enveloping the bones before they had time to be generally removed by decay under the influences of the weather and infiltrating air and water. From the horizon of the skeleton, the loess extends up to the surface, a vertical thickness of 20 feet, and continues in a gently rising slope to a slight terrace on which Mr. Concannon's house stands. With similar irregularly eroded slopes, the loess continues upward to the general elevation of about 200 feet above the river within a distance of a fourth of a mile to a half mile southward and westward, attaining there a general level which was probably the surface of the river's flood plain at the maximum stage of the loess deposition. This plain appears to have been built up by gradual deposition from the broad river floods during many years and centuries, and to have stretched then over the present valley and bottomland of the Missouri, in this vicinity two to four miles wide, from which area it has been since removed by the river erosion. The great valley, as to its inclosing rock outcrops, is of preglacial age; it was not much changed by glacial erosion and deposition of the boulder drift; but it was deeply filled by the loess, in which the valley was afterwards re-excavated.

Professor Williston noted a distinct darker layer of loess, mostly about two inches thick but in part merely a threadlike line, traceable continuously through all the 72 feet of the west wall of the tunnel, running about 3 to 4 feet above the limestone floor, and one foot or a little more above the base of the loess. Pegs driven by our party at the line of this stratum along all its extent were seen to be in a straight plane, which by a hand level was found to have a descent of 7 or 8 inches

from south to north in this distance. Other lines of almost horizontal stratification exist, but are less observable, throughout the loess, which is thus clearly shown to be an aqueous deposit. Several small gastropod shells were found in it by members of our party, but they were too delicate to be preserved for determination of their species. Three others, which have been carefully preserved by Mr. Butts, are said to have been found at the same place with the skeleton.

To ascertain the date of this fossil man in the sequence of the time divisions or stages of the Ice age, we must have recourse to the classification of these stages in their chronologic order as defined during the last ten years by the field observations and writings of Chamberlin, James Geikie, and other eminent glacialists, both of America and Europe. In the United States we owe more to the careful studies of glacial geologists in Iowa than in any other state, in respect to the series and probable duration of the stages recognizable in the Glacial period. Calvin, McGee, Call, Leverett, Bain, Udden, Shimek, and others, have worked very advantageously on the drift series in Iowa; and their work has been supplemented, for the later drift deposits farther north, by Chamberlin, Salisbury, Winchell, Todd, and the present writer, in Wisconsin, Minnesota, the Dakotas, and Manitoba, and by the late Dr. George M. Dawson and his associates in the Geological Survey of Canada. From these very thorough explorations and discussions of the history of the Ice age, we have received, chiefly through the systematic correlations of Chamberlin, Dawson, Calvin, and Leverett, an elaborate classification of its successive epochs and stages, which, for definite statement of the geologic date of the loess and the Lansing skeleton, need to be here briefly noted, as follows.

1. The culmination of the Ozarkian epeirogenic uplift, in the later part of the Lafayette period, the earliest of the Quaternary era, affecting both North America and Europe, raised the glaciated areas to so high altitudes that they received snow throughout the year and became deeply ice-enveloped. Submerged valleys and fjords show that this elevation was at least 1000 to 4000 feet above the present height. Rudely chipped stone implements and human bones in the plateau gravel of southern England, 90 feet and higher above the Thames, and

the similar traces of man in early Quaternary sand and gravel deposits of the Somme and other valleys in France, attest man's existence there before the maximum stages of the uplift and of the Ice age. The accumulation of the ice-sheets, due to snow-fall on their entire areas, was attended by fluctuations of their gradually extending boundaries, giving the Scanian and Norfolkian stages, named by Geikie, in Europe, the Albertan formation of very early glacial drift and accompanying gravels, described by Dawson, in Alberta and the Saskatchewan district of western Canada, and an early glacial advance, recession, and re-advance, in the region of the Moose and Albany rivers, southwest of Hudson bay. In that region, and westward on the Canadian plains to the Rocky mountains, there seem to have been thus three stages recognizable in the glacial results of the epeirogenic uplift, namely, the Albertan early ice accumulation, the later time represented by the Saskatchewan gravels, of abundant glacial melting and extensive retreat, and afterward a vast growth of the continental icefields to their farthest limit, when they reached south to Kansas. The first recognized stage of glaciation in North America is therefore called the *Albertan stage*.

On the Atlantic coastal plain of the United States, south of the glacial drift, this stage is probably represented by the Lafayette formation; and the subsequent deep fluvial erosion of the Lafayette beds I attribute to the very long ensuing Aftonian and Kansan stages.

2. A deposit of glacial drift, the lowest and oldest observed in the Mississippi river basin, probably of Albertan age, stretches south at least to southern Iowa, where it is overlain by interglacial beds, inclosing peat, well displayed in sections at Afton, Iowa. The Aftonian interglacial time, especially notable for its extensive buried forest bed, containing trunks of hardy northern coniferous trees, has been ascertained to be earlier than the Kansan readvance of glaciation. It is therefore probably equivalent with the Saskatchewan stage of Canada, which name it should then displace according to the rule of priority. This second time division of the Glacial period, including a very important recession of the ice border, uncovering the previously glaciated country as far north, probably, as

to the southern half of Minnesota, is therefore named the *Aftonian stage*.

During this time, apparently, the Mississippi river in the vicinity of Minneapolis eroded a rock channel which is now mostly filled by the drift of the later glaciation, but is marked by a series of lakes, namely, Cedar lake, the Lake of the Isles, lakes Calhoun and Harriet, and others farther south. Prof. N. H. Winchell from his study of this interglacial channel of the Mississippi, has estimated the duration of the interglacial stage there as about 15,000 years.* It seems to be represented also in the history of the Quaternary lakes Bonneville and La Hontan, respectively described by Gilbert and Russell, as a prolonged stage of desiccation of those lakes under a drier climate, while their earlier and later flood stages are correlated with the Albertan and Kansan stages of glaciation. Near the southern limit of the glacial drift, the Aftonian interval was doubtless much longer than in Minnesota.

3. During the *Kansan stage* the ice-sheet attained its farthest extent in the Missouri and Mississippi river basins, and in northern New Jersey. It is correlative with the Saxonian stage of maximum glaciation in Europe. The area of the North American ice-sheet, with its development on the Arctic archipelago, was about 4,000,000 square miles; and of the European ice-sheet, with its tracts now occupied by the White, Baltic, North, and Irish seas, about 2,000,000 square miles.

4. In the *Helvetian stage*, named by Geikie from its recognition in Switzerland and elsewhere in Europe, the ice-sheets receded far from their Saxonian and Kansan boundaries. The Buchanan gravels and sands, as named by Calvin in Iowa, were deposited during the retreat of the Kansan ice-fields; and this time is also represented by the Yarmouth weathered zone and erosion of the Kansan drift, noted by Leverett in Iowa and Illinois. The greater part of the drift area in Russia was permanently relinquished during this stage by the much diminished ice-sheet, which also retreated considerably on all sides.

5. The *Iowan stage* was marked by renewed accumulation of snow and ice, extending over a part of the country that had been laid bare by the preceding retreat. Before the farthest

**Am. Geologist*, vol. X, pp. 69-80, with map and sections, Aug., 1892; and p. 302, Nov., 1892.



extension of this glaciation in Iowa, on the west side of the Wisconsin driftless area, the ice-lobe east of that area advanced from Illinois into the edge of southeastern Iowa, giving an Illinoian stage of glaciation which somewhat antedated the maximum of the Iowan, though not probably by a wide difference of time. Between the retreat of the Illinoian ice-lobe and the deposition of the Iowan loess, Leverett notes interglacial deposits and a zone of weathering, the records of his Sangamon stage. Iowan time seems correlative with the Polandian stage of renewed growth of the European ice-sheet.

In this late part of the Glacial period the northern lands, which had long stood at greater altitudes than now, sank at last under their heavy ice-load until they mostly were somewhat below their present highs. This Champlain depression, as it is called, permitted the glacial drift of coastal regions to be covered by fossiliferous marine beds, which through later re-elevation range up to 300 feet above the sea in Maine, 560 feet at Montreal, 300 to 400 feet from south to north in the basin of lake Champlain, 300 to 500 feet southwest of Hudson and James bays, and similar or greater altitudes on the coasts of British Columbia, the British Isles, Germany, and Scandinavia.

Glacial melting and recession from the Iowan boundaries was rapid under the temperate (and in summers warm or hot) climate belonging to the more southern parts of the drift-bearing areas when reduced from their great preglacial elevation to their present height or lower. The finer portion of the drift, swept down from the icefields by the abundant waters of their melting and of rains, was spread on the lower lands and along valleys in front of the departing ice, as the loess of the Missouri, the Mississippi, and the Rhine. In or just beneath the basal beds of the Missouri loess was the Lansing fossil man, belonging thus to the culmination or beginning of decline of the Iowan stage of glaciation.

To this time the Columbian formation seems referable, succeeding the Lafayette and its erosion in our Atlantic coast region. In a Columbian gravel deposit, at Claymont, Del., probably of a little later date than the base of the loess at Lansing, Mr. Hilborne T. Cresson in 1887 found an argillite implement, as described and figured by Prof. G. F. Wright in his works cited on a following page.

6. Moderate re-elevation of the land took place during the *Wisconsin stage*, in the northern United States and Canada advancing as a permanent wave from south to north and north-east. The ice border continued mainly in a wavering retreat along most of its extent, but attained its maximum advance in southern New England. This last well defined stage of the Glacial period was characterized by slight fluctuations of the ice front and the formation of prominent marginal moraines. Great glacial lakes were held by the barrier of the waning ice-sheet on the northern borders of the United States. At the same time the Mecklenburgian stage in Europe was attended by the formation of conspicuous moraine accumulations at the gradually receding ice boundaries in Sweden, Denmark, Germany, and Finland.

It is clearly seen, from this review of the Ice age, that the Lansing skeleton and the deposition of the loess are referable to its later part, when the high land elevation that caused the growth of the vast sheets of snow and ice was succeeded by the Champlain depression, which brought the period of glaciation to its end. Man at Lansing was contemporaneous with the beginning of the filling of the Missouri valley with the loess, probably a few thousand years before the very remarkable marginal moraines in Wisconsin, Iowa, Minnesota, and all our northern states, as well as in Canada, were formed on the boundaries of the departing ice-sheet. Most of the other observations of traces of men contemporaneous with glaciation in this country indicate merely an antiquity equal to that of the moraines formed during the glacial recession. Such are the discoveries of stone implements and the chips of their manufacture in the Late Glacial gravels of the Delaware valley at Trenton, N. J., in the similar valley deposits of Ohio, in the ancient floodplain of the Mississippi at Little Falls, Minn., in a beach ridge of the glacial Lake Agassiz in northwestern Manitoba, and the discovery of a fireplace under a beach ridge of the glacial Lake Iroquois in western New York, where geologists have found traces of man's presence during the closing scenes of the Ice age. For a comprehensive review of these traces of Glacial man, the reader may be referred to Wright's "Ice Age in North America" (1889), and his "Man and the Glacial Period" (1892).

Even these Late Glacial indications of man's existence in America, however, have been doubted in recent years by some of our ablest geologists and archæologists, for which reason Prof. W. H. Holmes, of the U. S. National Museum, has given much attention to this subject, visiting many of the reputed localities of evidences of man contemporaneous with the Ice age. His excavations and discussion of the locality of abundant artificially flaked quartz chips at Little Falls, Minn., led him to the conclusion that they were the work of modern Indians. But within the past year this place has been again very carefully studied by Brower and Winchell, with new excavations, leading them to refer the quartz chips to the later part of the Wisconsin stage of the Glacial period, while the waning ice-sheet yet covered the ground of the headwaters of the Mississippi.* To this view I have continuously given my support from the time when these quartzes were first brought to my attention by the paper concerning them presented by Miss Franc E. Babbitt at the meeting of the American Association in Minneapolis in 1883.

We owe to Prof. Winchell the first discovery twenty-five years ago, of artificial quartz chips at Little Falls referable to the Glacial period, his observations there in 1877 being published in the Sixth Annual Report of the Geological Survey of Minnesota. This was only one or two years after the earliest discoveries of stone implements in the glacial gravels of Trenton.

Brower gives to his work the title "Kakabikansing," which is the Ojibway word meaning Little Falls. His investigations, supplemented by aid of Prof. Winchell, seem to me to leave no room for doubt that men there, on the upper Mississippi river in central Minnesota, were contemporaneous with the accumulation of the great Leaf Hills moraine and with the glacial Lake Agassiz.

In the appendix of this volume I contributed a short paper, entitled "Primitive Man in the Ice Age," from which I may here quote two paragraphs to give my view of the probable

**Memoirs of Explorations in the Basin of the Mississippi: Volume V. Kakabikansing*, by J. V. BROWER, President of the Quivira Historical Society, with a Contributed Section by N. H. WINCHELL, President of the Geological Society of America, Councillors of the Minnesota Historical Society. Page 326; with many maps, and photographic illustrations of the quartz chips and implements. St. Paul, Minn., 1902.

only a third, or, as I think more probably, only about an eighth, so old as the flint hatchets of St. Acheul and other localities of the old world.

It will be objected, to my estimate of the antiquity of the Lansing man, that the subærial erosion, weathering, and various other features of the Kansan, Illinoian, Iowan, and Wisconsin drift deposits, with the associated interglacial beds, necessitate a much greater duration of these stages of the Glacial period than I have here suggested. Instead, I would reply that the old till sheets and the loess are spread somewhat evenly on the preglacial rock surface, all the valleys and grand topographic forms of the country in the southern part of our drift area being of preglacial origin. The drift earliest eroded from the preglacial land was also largely the residuary clays and decaying rock of the surface, accounting for the great contrast in composition of the more southern and the more northern drift deposits, even when of the same mode of formation and the same age.

Concerning the deposition of the loess along the Missouri river and on the older drift to long distances at each side, I think that its derivation chiefly from the englacial and finally superglacial drift is clearly demonstrable. Swept by the summer floods from the melting ice-surface, it was laid down as a deep valley drift deposit, thickening and lifting the great river on the vast floodplain until it flowed, during the hot part of each year, in a lakelike sheet of water, probably from 5 or 10 to 30 or 40 feet deep and far wider than the present bottomlands, at the general height of the loess bluffs and uplands. During the cool but not wintry parts of the year, in the spring and autumn, when the floods were reduced to comparatively small channels, or sometimes throughout several years together having less plentiful melting of the ice-sheet, land vegetation and air-breathing mollusks could occupy the newly deposited loess tracts. But the scantiness of vegetation on areas subject to summer overflow permitted the winds to carry off much of this very fine loess and to spread it over the contiguous country in massive swells and ridges, conforming in a general way to the previous contour. With decrease in the supply of both water and loess, when the Iowan ice-melting was nearly finished, the rivers eroded deep and wide valleys in their loess plains, the valley of the Missouri

ranging from three to fifteen miles in width, and attaining a depth below its present bottomlands.

During the Wisconsin moraine-forming stage the land was re-elevated to about its present height. The Missouri and its tributary streams, laden with gravel, sand, and fine silt, supplied plentifully from the melting ice in this stage, built up again their floodplains to heights slightly above the present river bottoms. Between Sioux City and Council Bluffs, Iowa, a distance of 90 miles, this alluvial plain of the Wisconsin modified drift is mainly 6 to 12 miles wide on the east side of the river, a most fertile tract for corn-raising.

The Lansing discovery gives us much definite knowledge of a Glacial man, dolichocephalic, low-browed, and prognathous, having nearly the same stature as our people today. As stated by Prof. Williston, he was doubtless contemporary with the *Equus* fauna, well represented in the Late Pleistocene deposits of Kansas, which includes extinct species of the horse, bison, mammoth and mastodon, megalonyx, moose, camels, llamas, and peccaries. He was also the contemporary of the Late Paleolithic men of Europe, who in the Solutrian and Magdalenian development of implement-making from flint and bone, and in various other manifestations of artistic skill, were far advanced beyond primitive savagery.

It may be reasonably expected that many other evidences of the men of the loess-forming stage of the Ice age will be found, and will give some knowledge or hints of their mode of life. Two such items of testimony are already known in Iowa. Prof. F. M. Witter, superintendent of schools at Muscatine, in a paper read before the Iowa Academy of Sciences in 1891, described "a rather rudely formed spear point of pinkish chert," found in the loess in that city about 12 feet from the surface, and an arrow point in the same loess section, "at least 25 feet below the surface." Both were discovered in place by Mr. Charles Freeman, the proprietor of a brickyard. Again, in volume XI. of the Iowa Geological Survey, published last year, Prof. J. A. Udden, reporting on Pottawattamie county, writes: "In tunnelling the cellars into the loess hills back of Conrad Geisse's old brewery, on Upper Broadway in the same city [Council Bluffs], it is claimed that a grooved stone ax was taken out from under thirty feet of loess and forty

feet from the entrance of the cellar excavation. The ax has an adhering incrustation of calcareous material on one side, evidently deposited by ground water. The loess at this place has possibly been disturbed by creeping or by rain wash, but its appearance suggests nothing of the kind. It is quite typical loess for this region. The ax was discovered by the workmen engaged in excavating the cellar and immediately shown to Engineer Robert F. Rain, who superintended the work, and who still has possession of it."

Since man is shown to have lived in this region, probably 10,000 to 15,000 years ago, with elephants and mastodons, it seems quite possible that he left some token of them in the forms of some of his mounds, or in their contents, as the much discussed sandstone pipes found in Louisa county, southeastern Iowa, and owned by the Davenport Academy of Natural Sciences, carved to represent the elephant or mammoth of the Ice age. In Europe, at about the same time, the spirited carvings of the outlines of mammoths and reindeer, on their own tusks and antlers, by the Late Paleolithic men, give indubitable evidence that they and these animals of the Glacial period subsisted together. Indeed, very probably the extinction of the mammoth, and of the horse in America before Columbus came, may have been due to the prowess of the aboriginal hunters in killing them for their food.

THE TRAINING AND WORK OF A GEOLOGIST.*

C. R. VAN HISE, Madison, Wis.

GEOLOGY is a dynamic science, subject to the laws of energy. Geology treats of a world alive, instead of, as commonly supposed, a world finished and dead. The atmosphere, or sphere of air, is ever in motion; the hydrosphere, or sphere of water, is less active, but still very mobile; the lithosphere, or sphere of rock, has even slower, continuous, although slow, motions. The motions of the atmosphere, the hydrosphere, and the lithosphere affect one another, and by which the positions of land masses, of mountains, of islands, and interior motions, of high plateaus, and of low lands, are constantly rearranged

*The Journal of the Geological Society of America, Vol. 10, No. 1, p. 1, 1902. Reprinted from the *Transactions of the Geological Society of America*, Vol. 10, No. 1, p. 1, 1902.

with reference one to another, and indeed are constantly remade. Furthermore, the molecules and even the atoms which compose the atmosphere, hydrosphere and lithosphere have motions of marvelous intricacy and speed. These motions of the atmosphere, the hydrosphere, and the lithosphere are all superimposed upon the astronomical motions—the wobbling revolution of the earth about its axis, the revolution of the earth-moon couple about their common center of gravity, the movement of this couple about the sun at the rate of 68,000 miles per hour, the movement of the solar system among other systems. If it were possible for one to fix in space coordinates by which to measure these various motions, the movement of an air particle, of a water drop, of a mineral grain, would be seen to be extraordinarily complex.

It is clear that there is every reason to believe that no atom or molecule in the world ever occupies the same absolute position in space at any two successive moments. Indeed, it must have been an extraordinary accident, if a single particle has occupied in all the history of the universe exactly the same position that it has occupied at any previous time. No such thing as rest for any particle of matter anywhere in the earth or in the universe is known. On the contrary, everywhere all particles are moving in various ways with amazing speed.

No science is independent of other sciences, but geology is peculiar in that it is based upon so many other sciences. Astronomy is built upon mathematics and physics. Chemistry and physics to a considerable degree are built upon each other. Physics also requires mathematics. Biology demands a limited knowledge of physics and chemistry. However, it cannot be said that a knowledge of the basal principles of more than one, or at most two, other sciences is an absolute prerequisite for a successful pursuit of astronomy, chemistry, physics or biology. This is not true of geology. In order to go far in general geology one must have a fair knowledge of physics, chemistry, mineralogy and biology. These may be called the basal sciences of geology. In certain lines of geology the additional sciences, mathematics, astronomy and metallurgy, are very desirable.

Geology treats of the world. In order to have more than a superficial knowledge of geology, it is necessary to know about the elements which compose the world, how force acts upon these elements, what aggregates are formed by the elements and forces, and how life has modified the construction of the world. Chemistry teaches of matter; how it is made up, both in life and in death. Without an understanding of its principles we cannot have an insight into the constitution of the earth or of any part of it. Physics teaches of the manner in which the many forms of that strange something we call force acts upon matter. Without a knowledge of its principles we can never understand the transformation through which the world has gone. The elements which compose the earth are combined under the laws of physics and chemistry into those almost life-like bodies which we call minerals. The minerals are commingled in various ways in the rocks. Without a knowledge of mineralogy no one can have even a superficial understanding of the constitution of rock masses. Biology teaches of the substances alive which clothe the outer part of the earth. Life is one of the most fundamental of the factors controlling the geological transformations in the superficial belt of weathering; it has acted as the greatest precipitating agent in the sea. Life has had, therefore, a profound and far-reaching effect in determining the nature of the sedimentary formations.

The sciences of chemistry, physics and biology have been built up by using minute parts of the materials of the world. If geology, or a science of the earth, is to be constructed, it must apply to the earth as a whole the principles which have so enlightened us as to the nature and relations of the fractions of the world which we observe and handle in our laboratories of physics and chemistry and biology.

It thus appears that geology is a composite science. It might, in a certain sense, be called an applied science. Indeed, I have often defined geology as the application of the principles of astronomy, of physics, of chemistry, of mineralogy and of biology to the earth.

Certainly the earth is the single enormous complex aggregate of matter directly within the reach of man. This highly composite earth is the joint result of the work of astronomical, physical, chemical, and biological forces, working on an in-

comparably vaster scale than can ever be imitated in our laboratories. A study of these mighty results has already advanced at many points astronomy, physics, chemistry, and biology, and future studies, made with direct reference to the causes which have produced the earth, are sure to lead to even greater advances in these sciences.

If geology is to become a genetic science, or more simply, is to become a science under the laws of energy, geology in large measure must become a quantitative science. In the past it has been too frequently true that because a single force or agent working in a certain direction is a real cause of a the phenomenon; another holding that this is the explanation, cause. Only occasionally has the question been asked 'Is this cause not only a real cause, but is it an adequate cause?' Very often differences of opinion have arisen between geologists, one holding that this cause is the one which explains the phenomenon, another holding that this is the explanation, and each insisting that the other is wrong. In such cases very rarely is the question asked whether the explanations offered are *contradictory* or *complementary*. In many cases the explanation is not to be found in one cause, but in several or many, and thus frequently the conclusions which have been interpreted to be contradictory are really supplementary. To illustrate: But few writers have assigned more than a single cause for crustal shortening. One has held that secular cooling is the cause; another has given a different one, and has held that secular cooling is of little consequence. But it is certain that secular cooling, vulcanism, change of oblateness of the earth, change of pressure within the earth, changes in form of the material of the earth, and various other causes are not exclusive of one another, but are all supplementary. The ability to perceive the supplementary nature of various explanations offered for a phenomenon is one of the most marked, perhaps the most marked, of the characteristics of the superior man. The new geology must not only ascertain all of the real causes for crustal shortening, and other phenomena, but in order satisfactorily to solve the problems it must determine the quantitative importance of each. Geology within the next few years is certain to largely pass to a quantitative basis.

If I have correctly stated the relations of geology to the other sciences, it follows as a corollary that those only can greatly advance the principles of geology who have a working knowledge of two or more of the sciences upon which it is based.

By a working knowledge of a science I mean such a knowledge of its principles as makes them living truths. One must not only be able to comprehend the principles, but he must see them in relations to one another; must be able to apply them. It is not sufficient for a carpenter to be able to explain how the hammer, saw, plane, and chisel work; he must be able to use them. He must be able to hit the nail on the head, to cut straight, to plane smooth, to chisel true, and do all upon the same piece of timber so as to adapt it to a definite purpose in a building. Just so the geologist must be able to apply as tools the various principles of physics and chemistry and biology and mineralogy to the piece of geology upon which he is engaged; and thus shape his piece to its place in the great structure of geological science. This is what is meant by a working knowledge of the sciences basal to geology.

It is not supposed that any one man has a comprehensive knowledge of all the basal sciences, or even a working knowledge of their principles; but such knowledge he must have of two or more of them if he hopes to advance the principles of geology. He will be able to handle those branches of his subject with which he deals in proportion as he has a working knowledge of the basal sciences upon which his special branch is based, and will properly correlate this branch with the other branches of the great subject of geology in proportion as his working knowledge of the basal sciences is extensive.

For instance, to advance geological paleontology one must have a working knowledge of the principles of biology and of stratigraphy. To advance any of the lines of physical geology, one must have a working knowledge of the principles of physics, and especially of elementary mechanics. To advance physiography one must have a working knowledge of physics and chemistry. To advance knowledge of the early history of the earth, one must not only have a working knowledge of physics and chemistry, but of astronomy. To advance petrology, one must have a working knowledge of physics, chemistry and miner-



alogy. To advance the theory of ore deposition or metamorphism, one must know not only the principles of physical geology, with all that implies; but he must have a working knowledge of chemistry, mineralogy, and petrology. It is unnecessary to add that a geologist must be able to read some of the modern languages, and be able to express himself clearly and logically in one language.

Considering the breadth and thoroughness of the necessary preliminary training for the successful pursuit of geology, one might anticipate that geology would suffer but little from pseudo-scientists. But this anticipation is based upon the idea that no one attempts geological work, and especially to write geological papers, until he is prepared to do so. All sciences have their cranks. Many a little town has its philosopher who believes that all of the principles of astronomy, of physics, of chemistry, which have been discovered by the great men of the past, are absolutely erroneous, and who makes a new start upon the construction of the world, building out of his brain strange vagaries which have no relation to the facts of the universe. While there are temptations to pseudo-scientific work in all sciences, the temptation is nowhere so great as in geology. The planets, sun and stars, are far off; the elements are elusive; to do anything with force one must have at least seen the inside of a physical laboratory; the manner of the transformations of living forms is not obvious, or even apparently so, and few write about the constitution of plants and animals who have not closely studied them. But one is born upon the earth; he lives upon the earth; he sees the surrounding hills and valleys. The dullest sees something of the transformations going on. Many naturally become interested in the phenomena of the earth and, without preparation, think that they are able to make important contributions to the subject of geology. Thus not only in every city, but in many villages, is a geologist of local repute who has ready explanations for the order of the world.

Geology starts as an easy observational study, and gradually becomes more and more complex until it taxes the master mind to the utmost. This easy start leads to the multitude of local geologists, but geology suffers comparatively little from them. The real injury which the science receives is from

some of those who call themselves professional geologists, are teachers of geology in academies and colleges, or even members of the staff of state or government surveys. These men have gone further than the local geologist, but perhaps they have been led into the subject for somewhat the same reason,—its easy start as an observational science. A man may begin his career as a geologist by making a few observations here and there and giving a guess as to their meaning. With this beginning he becomes more and more interested, until finally he decides to make geology his profession.

In some cases, following this decision, the necessity is seen for obtaining a working knowledge of the basal sciences. But too often men who have entered upon geological work have received no adequate training in chemistry, in physics, in biology, and therefore at the outset wholly lack the tools to successfully interpret the phenomena which they observe. Such inadequately trained men feel that a satisfactory explanation of any phenomenon must involve a statement of the underlying chemical or physical or biological principles, and in such cases it is safe to say that the explanations given are extremely partial, including only a modicum of truth, and more often than not are absolutely fallacious. Indeed, no other result can be expected from one who lacks a working knowledge of the principles of physics, chemistry, and biology. Occasionally there is a clear-sighted, capable man, lacking in adequate training, who does important geological work simply because he knows his limitations, and there stops. But this is very exceptional indeed; and the physical explanations offered by many for various geological phenomena are no less than grotesque.

It has been made plain that a working knowledge of the sciences basal to geology is necessary in order to advance its principles. But I go even further, and hold that such basal knowledge is absolutely necessary in order to do even the best *descriptive* work. Suppose a man to be standing before some complex geological phenomenon. The whole intricate interlocking story is engraved upon the retina of his eye with more than photographic accuracy. The image on the retina is absolutely the same in the eye of this experienced geologist and that of a child. Yet if the child be asked to state what he

sees, his statements will be of the most general kind and may be largely erroneous. The experienced geologist with a knowledge of the principles of physics and chemistry and biology interprets the phenomena imaged in terms of these subjects. The engraving on his retina is the same as that of a child, but his brain perceives the special parts of the picture of interest to him in their true proportions. He understands what is important, what is unimportant. He must select and record the things which are important. If he attempted to record all that imaged in his eye, a notebook would be filled with the phenomena to be described at a single exposure, and yet half the story would not be told. Good descriptive work is discriminative. Good descriptive work picks out certain of the facts as of great value, others of subordinate value, and others of no value for the purposes under consideration. How then can this discrimination be made. How can the facts be selected which are of service? Only by an insight into the causes which may have produced the phenomena. Without this insight to some extent at least a description is absolutely valueless. So far as the geologist has such insight, his description is valuable.

It is frequently urged in opposition to the above that, 'If a person has theories in reference to the phenomena which he observes his descriptions will be erroneous; he will be biased by his theories.' Unfortunately in many cases this is so; but just so far as it is true, the man fails of the qualities which make a successful geologist. One's theories undoubtedly control in large measure the selection of the phenomena which are to be noted, and the wisdom of the selection is a certain criterion of the grade of the geologist. But whatever the facts selected for record, the statement of them should be absolutely unbiased by the theories. Invariably, good practice requires that the statement of facts and the explanation of these facts shall be sharply separated. Doubtless each geologist who is listening has at different times had different ideas about the same locality, or while away from a locality a new idea has come as to the meaning of the phenomena there observed. Upon returning to the old locality with the new idea, additional observations of value have been made. But all the statements of facts at the previous visits should be found to be absolutely true. In so far as they are untrue, the geologist fails of accuracy, the

first fundamental of observation. If the previous observations are found to be largely erroneous, the man who made them has small chance to become a good geologist. The difference between *bad* observation and *good* observation is that the former is *erroneous*; the latter is *incomplete*. Unfortunately in many cases not only are the observations recorded by many men absolutely false, but they are so intertwined with the theories of the author that one is unable to discriminate between what is intended to be fact and what is advanced as opinion. It is needless to say that the case of such a man is hopeless; that there is no possibility that he shall ever become a geologist. I conclude, therefore, that in order to have a standing in the future, even as a descriptive geologist, one must interpret the phenomena which he observes in the terms of the principles of astronomy, physics, chemistry, mineralogy, and biology.

If my statement thus far be true, the outline of the training of a man hoping to become a professional geologist is plain. Such a man should take thorough and long courses in each of the subjects of astronomy, physics, chemistry, mineralogy, and biology. This means that a large part of the training of a geologist is the study of the sciences upon which geology is founded. If a man who hopes to be a geologist is wholly lacking in a knowledge of any of the basal sciences, this defect he can probably never make good. Even if he so desires, the time cannot be found. Moreover, chemistry, physics, mineralogy, and biology are laboratory sciences and can be satisfactorily handled only in the laboratory. If the fundamental work in the basal subjects has been done in the college or university, one may keep abreast of their progress during later years, but in order to do this, the basal principles must have become living truths to him while a student. If a personal illustration be allowable, during the past five years, in order to handle the problems of geology before me, I have spent more time in trying to remedy my defective knowledge of physics and chemistry and in comprehending advances in these sciences since I was a college student than I have spent upon current papers in geology, and with, I believe, much more profit to my work. If one has a working knowledge of the basal sciences and lacks training in some branch of geology, this defect he may remedy, for he has the foundation upon

which to build. But if he lacks knowledge of the primary principles of the basal sciences he is likely to be a cripple for life, although this is not invariably the case. There are conspicuous instances where lack of early training in the basal sciences has been largely remedied by unusual ability and industry, but this has been most difficult. We should see to it that the young men trained in our colleges and universities, upon whom we place the degree of Doctor in Geology, are not crippled by the necessity of making good in later life defective basal training. Any university which gives a man the degree of Doctor in Geology with a defective knowledge of the basal sciences is wronging the man upon whom the degree is conferred; for this man has a right to expect that his courses shall have been so shaped as to have given him the tools to handle the problems which will arise in his chosen profession.

It is not necessary that all of the basal work shall be done before a man begins his life work, but at least a large part of this work should have been done before a man is given the certificate that he can do the work of a professional geologist. But in any case studies in the basal sciences should not cease when the professional degree is granted. Continued studies not only in the basal subjects but in cognate branches and even those far removed from science should continue through life. The geologist finds that however broad and deep his studies are in basal and cognate subjects, that he is continually limited by lack of adequate knowledge of them.

In recent years it has been a moot question in colleges and universities as to when specialization should begin, rather implying that when specialization begins broadening studies should cease. And, indeed, it is upon this hypothesis that most of the discussion upon this subject has been carried on. Some have held that specialization should not begin until late in the college course, or even rather late in a postgraduate course. Others have held that one should early direct his studies to special subjects which he expects to pursue, and give comparatively little time to other subjects. The argument for this latter course is that competition is now keen, and if a man keeps in the race he must begin to specialize early. It appears to me that both of these answers are inadequate. My answer to the question is that specialization should begin early,

but that broadening studies should *not* be discontinued. This rule should obtain not only through the undergraduate course, but in the postgraduate work and during professional life. The specialized work will be better done because of the broad grasp given by the other subjects. The broadening studies will be better interpreted because of the deep insight and knowledge of a certain narrow field. Thus each will help the other. No man may hope for the highest success who does not continue special studies and broadening studies to the end of his career.

But is it held that a geologist lacking an adequate working knowledge of basal studies cannot perform useful service? No, the domain of geology is so great, the portion of the earth not geologically mapped and the structure worked out is so vast, the ore and other valuable deposits which have received no study are so numerous, that there is an immense field for the application of well-established principles. In geology, as in engineering and other applied sciences, there is an opportunity for many honest, faithful men to perform useful service to the world even if their early training and capacity are not all that could be desired. But even the application of old principles to new areas will be well done in proportion as the geologist has training in the basal sciences, and to the man who combines with such training talent must necessarily be left the advancement of the philosophy of geology. The philosophy of geology, the inner meaning of phenomena, was the paramount consideration to Hutton and Lyell and Darwin. To them facts were useful merely that they might see common factors, the great principles which underlie them. In other words, generalization. The training of a geologist involves the capacity to hold in the mind a number of facts at the same time: to see them in their length and breadth and thickness; to see them at the same time as large masses and as composed of parts, grains, cells, instrument, mineral particles and the elements, to see the principles of chemistry and physics and mineralogy and to be grasping the significance of them only by holding them in the mind as grains and particles in one's mind at the same time, and to see them in the light of some general laws.

Geology is a collection of facts and a large number of facts put together as they look in this scene or that in a single

book, or a single chapter, or on the same page, or even in the same paragraph or sentence, are contained ideas which are exclusive of one another. They are not seen by the writer to be exclusive of one another because he is so lacking in a command of the principles of the basal sciences that he is not aware of the antagonism. Major Powell once said to me, 'The stage of the development of the human mind is measured by its capacity to eliminate the incongruous.' If this hard criterion were rigidly applied, it would follow that many of our profession have not passed the youthful stage. The man who can insert in the same treatise, chapter or page incongruous ideas saves an immense amount of cerebral tissue for himself. Such a man can write on through chapters and books, and not find it necessary to go back, adjust and interrelate the various parts. There is no action and reaction between the multitude of ideas. The writer has the easy task of holding in his mind at any one time but a few data. He is in delightful and happy unconsciousness of the fact that many of his statements destroy one another. But the man who sees the phenomena and principles of geology in all their complex relations, tries to express the parts of them he is considering in proportion to one another, and to place his fragment of the science of geology in proper relations to other departments of geology and other natural sciences, has a task before him requiring great mental effort. He must see and understand in three dimensions. At every point he must see the lines of cause and effect radiate and converge upon the phenomena he is considering from many other phenomena and principles. Of course all fail to do this completely in reference to any complex problem. All fail to reach the ultimate truth. To do so would require infinite capacity. But in so far as success would be attained, the effort must be made. In proportion as one can hold many facts and principles and see their interrelations, he will be able to advance the philosophy of geology. This is the work which burns the brain.

And his results he must express in language, the chief means of communicating ideas and relations. Yet language is linear. By figures, models, maps and other illustrations, wisely used, one may to an important degree remedy the defects of linear language. Yet language and illustration, even where used

to the best advantage, but poorly convey one's ideas. Most conscientious writers require as much or more time to put a complex subject into words and illustrations ready for publication as they do in working out the results.

But upon the other side, and in favor of expression in language, it should be remembered that there is action and reaction between one's ideas and the attempt to express them in words and illustrations. The necessity for expression in language is often a wonderful clarifier of ideas. The ideas are improved by the attempt at expression, and the expression is continually improved as the ideas are enlarged.

That the difficulty as to expression does not apply to geology alone is well illustrated by the vast amount of labor Charles Darwin spent in putting into the linear form of language the most revolutionary work of the time, 'The Origin of Species.' It seemed as if the intricately interrelated facts of life were of so complex a nature that language could not handle the problem. But the genius of Darwin was such that he not only conceived the idea of natural selection and proved its truth to his own mind, but he so marshalled his facts and principles in linear form in one volume that men were forced to believe. Many of the ideas contained in single sentences or paragraphs of the 'Origin of Species' have been expanded into papers, volumes or treatises by others, and thus made easier to comprehend. The 'Origin of Species' has often been said to be a difficult book to read. So it is, because its ideas are more complex than language can easily convey. Darwin unquestionably saw deeper than he was able to express, and it was the struggle to state what he knew which made the writing of the 'Origin' such an onerous task. But geology as a whole is only less complex than life; and many of us in the smaller matters with which we are attempting to deal have felt the impossibility of conveying more than imperfectly the ideas and relations which are in our minds.

In thinking of the marvelous complexity of the phenomena of geology, and seeking for an analogy which might in some measure express this complexity, it seemed to me that the inhabitants of the globe and their intricate relations furnish an approximate illustration. From each individual or family or hamlet or city or metropolis, there go out on foot, by wheel, by

wagon, by railway, by vessel, various products some of them to the remoter parts of the earth. From each center, by letter, telegram, telephone, communications diverge; if the center be a large one, by thousands of lines. To each center, materials and thoughts in a like manner converge. In a similar way one class of geological phenomena is related to nearly all other classes. They are related as to their material parts, as to the forces and agents acting, and as to principles concerned in their production. For instance, an economic geologist will appreciate that the development of an ore deposit depends upon the nature of the adjacent rocks, upon earth movements, upon the resultant deformation, upon fractures, upon vulcanism, upon erosion by water and ice and wind, upon the circulation of underground water, upon complex physical and chemical conditions. One who hopes to gain even an approximately adequate idea of the genesis of an ore deposit, and an insight as to what is probably beyond the point where the deposit is 'shown up,' must be able to handle the intricate principles of geology. In so far as a geological or mining engineer is a master of these, he rises in his profession. In so far as his knowledge of facts and principles is meager, an ore deposit seems a lawless thing which can be only dealt with on the relatively simple principles of the doctrine of chances,—if an ore body happens to be found at any place, follow it; if for some **unknown reason** it is lost or depreciates in value, prod the **ground in all directions**, up and down, to the right and left in **the blind hope that chance may find more ore**. In many cases nine-tenths of this expensive chance work would have been shown in advance to be wasted, had the mining engineer a fair knowledge of the occurrences, relations and principles of ore deposits.

If the statement that geology is founded on truth, the training of a geologist is a **intellectual point of view**. It is the **all departments of** learning essential to the **subject is necessary** for a **each of half a** dozen **economics,** English **dissatisfaction** that **educated** it **and at** in **in**

reference to certain subjects. The claim that this or that subject is essential to a liberal education shows a lack of breadth and lack of capacity to see things in their proper proportions. No one language or science is essential to a liberal education. But while this is true, it does not follow that this or that subject may not be essential for a particular career. Far be it from my purpose to speak in a derogatory way or to underestimate the value of any line of knowledge. At the present day a man who is trained only in science or only in the humanities has but one hand; that hand may be strong, but the man can never control the affair before him with the power, with the nicety, with which does the man with two hands, one of which is the rich treasures of science, and the other the no less rich and important treasures of the humanities, each doing its part in harmony, with corresponding fullness of results. With a fundamental knowledge of both the scholar of the future may choose as his chief occupation the clear, cold work of science or the attractive work of the humanities, which will always have more numerous followers, because of their direct personal interest.

As I have already intimated, I hold that for the best liberal education one must pursue broadening studies from the first to the last, and also that one must begin early to specialize. If this be true, geology may be said to be a very desirable part of a liberal education, for it is built upon the whole realm of pure science, *i. e.*, the knowledge which applies not only to the earth and all it holds, including man, but to the universe as well. Because of the breadth of training combined with specialization required of a geologist, it might be shown that geology is one of the most useful studies in giving a person a sense of proportion, ideas as to relative values, of perspective, qualities of the first order in this world. It might be held that the intellectual training of the geologist is of a kind which helps him in dealing with men and things, and, therefore, for handling the world's work. But time does not suffice to develop this part of the subject.

I shall now suppose that a geologist is adequately trained, that he has some power in generalization, and consider what should be his method of work. It is assumed that the young geologist spends a part of each year in the field. This field

work should include areal mapping with structural and genetic interpretations. The more widely a young geologist has traveled, the more numerous the excursions in which he has taken part, the better will be his equipment. But no general work such as this can supply the place of systematic mapping. And the more exact the mapping is, the better the training. Very frequently the educational value of the mapping in detail of a small area is underestimated. Indeed, I hold that nothing else can take its place. Moreover, the only sure way to test a geologist is to require him to delineate upon a map and in structural sections the detailed phenomena of the field. For my part I have more confidence in the future of a young geologist who has mapped in detail twenty-five square miles, and has got out of the area much that is in it, than that of another who has done no detail work but has run over and written about thousands of square miles. Rarely can the general conclusions of a man who has not done systematic mapping be relied upon. In America there have been conspicuous cases of men calling themselves geologists who have never carefully mapped a square mile. Yet some of these by the indiscriminating have been regarded as leading geologists. And in one or two cases these men have gained a wide hearing. But the systems which they have built up have little or no relation to the world, and they have disappeared with the death of their authors. A geologist must not only do systematic field work at the outset, but he must continue to do such work through the years to a ripened age. Not infrequently a geologist, who in early life has done systematic field work, drops this work and continues writing geological philosophy. This is a precarious course, which sooner or later makes of him what one of our members calls a 'closet geologist.' It is only by never ending action and reaction between the observation of complex phenomena of geology in the field and reflection as to the meaning of the phenomena that sure results can be obtained.

While one should spend a part of each year in the field, I suspect that many more discoveries of geological principles are made in the office or in the laboratory than in the field. The cow collects the grass in the meadow and afterwards lies down to chew the cud and digest the food. So the geologist in the field, in the midst of innumerable facts, collects all he

can. His notes are a record of his daily collections, and, if a successful geologist, of his daily imperfect inferences and deductions. But during the eight or nine months of office and laboratory work he has full opportunity for reflection. He is then likely to see more of the common factors of the facts collected, and is more likely to see deeper into the underlying principles which explain them. This is still more true of the facts collected during previous years than in the current year. Indeed, in the field the observations of the current year are often too prominent on account of their recency, and it is only after some months have elapsed that they take their true proportion to observations of previous years. The use of the material collected not in one year only, but through many years, is necessarily in the office or in the laboratory, and it is only from such large masses of material that broad generalizations can be made.

The inductions and deductions made in the office and the laboratory during the winter should be tested in the field in the following year in the light of the new ideas. The new ideas should not by a fraction modify the correctness of the observations of the previous years; they should be found as accurate as when made. But observations are always incomplete, and with a new idea one invariably adds valuable observations which were not noted before the idea was available.

I once wrote to a number of geologists of this and other countries, asking the directions and dips of the dominant cleavages and joints for the various districts and regions of the world with which they were familiar. From only a single geologist did I obtain data of value. Some geologists wrote that they had not time to observe such subordinate phenomena! These men had evidently not learned the principle that the small but numerous agents or forces or structures may have as great or greater importance than more conspicuous but less common ones. Darwin should have taught every scientist the principle of the quantitative importance of the small factor when he showed how great is the work of the apparently insignificant earth-worm. It seems to me that joints are one of the important phenomena of geology; and this is true whether the point of view be deformation alone, physiography, metamorphism, circulation of groundwater, or the genesis of ores.

While the work of each geologist should be based upon thorough field and office work, and thus have an inductive basis, one should not there stop, but should by deduction ever be looking forward. No one ever held more firmly to fact as a basis for induction than Darwin, but also, no man has more successfully projected by deduction beyond his facts than Darwin. This in biology was a task of extraordinary difficulty. In geology one who has a firm grasp of the principles of physics and chemistry may be more daring. Their principles, if not more definite than the laws of biology, are at least better known and more simple. Therefore, one, after having observed the facts in a district and grasped the principles which explain them, may deduce what are likely to be the facts in the field and their relations in advance of observation. Or more concretely, after one gets the correct idea as to the meaning of the phenomena for a certain district, he often can tell in advance of observation what he will see,—or can find what I call 'geology made to order.'

There is no better or more severe test of a theory than one's capacity to find geology made to order. If observation of an area shows facts are not as expected, this is certain evidence that one or more factors in the problem have been omitted and that the theory is inadequate. In so far as the theory is adequate, the geology will be found as anticipated. The reason for this is the very great complexity and delicate adjustment of the phenomena of nature. To illustrate, if the many parts of some complex machine, such as a great printing press, or a chronometer, were scattered far and wide, and then one should gather many of these parts, and try to fit them, he might find that certain numerous parts fit perfectly. If this were so, he would know to a certainty that these parts are in the correct positions and relations, even if he did not know the relations of these parts to other parts or the purpose of the whole; for so complex and exact is the adjustment that there is but one way to put the parts together. Another set of parts might be found and these made to fit. But doubtless certain parts would not be found. These would be missing links necessary to make a perfect machine. In this situation, if the man had a genius for mechanical construction and an insight into principles, he might be able to understand the purpose of the whole, and finally to

supply the parts which render the whole a useful machine. This he would be able to do just in proportion as he had mechanical insight.

So the geologist fits together his numerous diverse facts. If he finds a solution of his problem which gives accordance to all the numerous facts observed, he may be sure he is on the right track even if he is incapable of seeing the full truth, for so delicate is the adjustment of facts that where they are numerous there is usually only one way to put them together. Just in proportion as the man has a working knowledge of the principles of physics and chemistry and biology and the other cognate sciences will he be able to eliminate erroneous explanations, combine the facts into groups under true theories, and correctly infer how the different groups are to be adjusted, how the various facts which seem at first to have no definite relations are related. Or, to put it in another way, in proportion as he knows the rules of the game will he be able correctly to interpret the meaning of phenomena and from them to project into the unknown. The importance of understanding the rules of the game is not often appreciated. To the person who is ignorant of the principles of the various sciences all things are possible. So many wonderful things have happened within the past half century that he thinks it possible for anything to happen. He has no principles by which he can determine whether or not a statement is probably true. Hence all sorts of grotesque notions flourish. Indeed the very fact that so many wonderful things have been accomplished makes many more ready to regard as possible almost any absurdity announced by some so-called 'professor.'

Perhaps at no time in the history of the world has the public shown more ready credulity than at present. Indeed, it seems as if the more grotesque and preposterous an idea the more likely it is to receive attention. And this credulity is not confined to those who are altogether ignorant of science. A man may be a very narrow expert in one direction of science and be wholly ignorant of the rules of the game in reference to another science. For instance, when an eminent biologist says 'bell-ringing, the playing on musical instruments, stone-throwing and various movements of solid bodies, all without human contact or any discoverable physical cause—still occur among us as they have



occurred in all ages,* the statements show the author to be so lacking in a comprehension of the principles of physics that he is unable to estimate whether or not a phenomenon of physics is likely or not likely to be true. It is clear that a man may be an authority as to biology, and yet be so ignorant of the rules of physics that he may be as simple as a child in reference to that subject. Upon the other hand, a man who has a firm understanding of the principles applicable to a case, or, in other words, knows the rules of the game, is likely to be able to reach a rather definite conclusion as to whether or not an explanation which suggested itself is in accordance with those rules, and therefore may be true, or disagrees with some of the well established rules, and therefore is not worth considering.

A geologist once said to me of my teacher and early geological guide, professor Irving, that he was more correct as to the structure of the Lake Superior region than he ought to have been. But I say that every man is just as correct as to deduction beyond observed facts as he should be. Men with defective basal training and poor intellectual power will always fail when they try to put facts together under principles, and especially when they attempt to project by deduction beyond observed facts. But men who have a firm grasp of the principles of the sciences basal to geology, the capacity to correlate these principles, and apply them to the facts of geology, will go beyond their observations and by deduction will reach conclusions with perfect confidence which are far in advance of observation. Indeed in this way only can the best geological work be done. After one has projected his deductions in advance of observations, he returns to the field with these new ideas, and then carries his observations further than he was able to do before. The geologist whose ideas are not continually outrunning his observations will never go far in the science. He whose mind is behind his observations instead of in advance of them, will ever be mediocre. The minds of the leaders of geology are on the mountain heights before their feet have more than touched the foothills.

The conclusions deduced by a scientific genius may go so far in advance of observations that he who announces the con-

* "The Wonderful Century," by ALFRED RUSSELL WALLACE, p. 211.

clusions may not be able to make observations which confirm the theories during his lifetime. In such cases subsequent observations made through many years by others will find the phenomena confirming the principles. The truths announced by the man of insight are often not accepted by slower men until this latter observational work is done. Many cases could be cited illustrating these statements. Darwin, in 1860, *knew* that life had existed that would fill in the great gaps in the very imperfect paleontological record. Since 1860 all the greater gaps have been filled by discovered fossils. Mendeleeff, when he saw the law of the periodic arrangements of the elements, *knew* the elements to exist which would fill the gaps, but it took many years of work by many men to find a part of them. During the past few years a half dozen or more of the vacant places have been occupied. Each geologist, each scientist, now as in the past, is just as right as he should be. The scientific seers will ever go far in advance and guide others, even as did the spiritual seers of old.

The scope of these observations doubtless extends beyond geology. Much of what has been said is true of knowledge as a whole, not restricted to one subject. But I shall have accomplished my purpose if what I have said be true of geology; for if my conclusions be well founded, they furnish the basis upon which courses leading to degrees in professional geology should be laid out, and to methods of good geological work in the field and in the office.

INFLUENCE OF COUNTRY-ROCK ON MINERAL VEINS.

By WALTER HARVEY WEED, Washington, D. C.*

AMONG the many causes of that perplexing feature of mine-exploitation, the unequal distribution of the ore, the influence of the country-rock upon the vein-contents has long been accepted as an important factor in certain districts, but the general application of the theory has not been proved. It is now possible to obtain trustworthy data with which to test the theory, and either to confirm or to overthrow this time-honored tradition. By the searching methods of modern petrography

* From the *Trans. Am. Inst. Min. Eng.*

and chemistry, rock-determinations are now scientifically made, while the examination of thin sections of ores supplements field and laboratory study, and affords conclusive evidence of the paragenesis of the ore-minerals.

In the great mass of data, regarding mineral deposits, accumulated during the past century, there are some facts which stand the test as to reliability; but the greater part are not available for use in this discussion. Within the last twenty years, however, many able workers have contributed careful and accurate accounts of various ore-deposits; and it is by the facts given in such papers, and by personal experience, that I have become convinced that there is in some districts a true relation between the country-rock and the mineral contents of the veins.

My own interest in the subject arose from the observation of a number of striking instances of the variation of vein-contents with the nature of the enclosing rock. Having already recorded certain observations of this kind, I venture to present in this paper further notes, together with a few facts from the literature of the subject, which seem to prove the correctness of my view. It is apparent that if the relation holds true, though in limited districts only, it will be of great practical interest to the miner, and will confer upon the geological survey of a mining district a new value, rendering it, in fact, an almost indispensable preliminary to the extensive working of large properties.

The influence of the enclosing rocks upon the mineral-veins evidently affects both the vein-structure and the vein-filling. The first effect is physical; the second is mineralogical or, primarily, chemical. The first has been but lightly touched upon, if noticed at all, by writers on mining geology. The second has long been recognized as a fact in a few well-known examples; but, although many attempts have been made to show a relationship between certain ores and definite rock-types, the correlations have been of local value only.

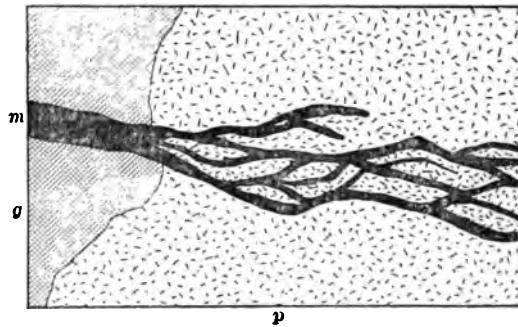
I. INFLUENCE OF ROCKS ON VEIN-STRUCTURE.

It is self-evident that in most mineral deposits the rocks must have been either porous or so fractured as to permit the circulation of underground waters as a preliminary to vein-formation. It is also evident that according to the varying hardness, tough-

ness, etc., of the rocks, the fissures found in them will vary in character, and the physical aspect of any resultant ore-deposit will be governed by the nature of the rock.

Fissure-veins, and, indeed, all forms of ore-deposits, are affected in size and shape, and probably to some extent in richness, by the character of the fissure or fracture in which the vein was formed. Experience shows that a vein often varies greatly in structural characters, such as width, uniformity, presence of splits and horses, etc., in passing, whether horizontally or vertically, from one rock into another. Thus the vein may pinch out in a very tough rock, expand in a more easily shattered material, become dissipated into a stockwork in brittle, shattered rock, or become lost entirely in a shale. In

FIG. 1



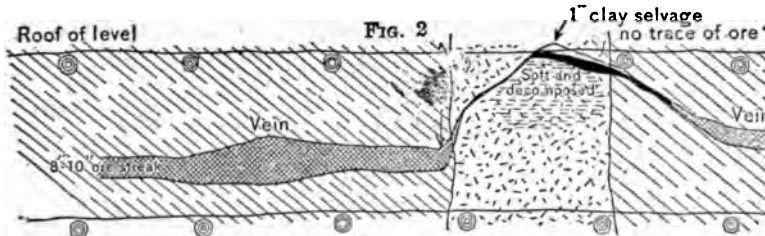
Scattering of the Gottlob Vein in Quartz-Porphry, in the David Shaft, near Freiberg, Saxony. *g*, Gray Gneiss; *p*, Quartz-Porphry; *m*, Vein.

easily soluble rocks, like limestones and dolomytes, the original character of the fissure may be modified by solution, and thus the original effects of its force may be masked. This case stands in such intimate connection with the mineralogical effects due to the nature of the rock that it is best considered in the second part of this paper. The irregular deposits formed in limestones show the influence of the enclosing rock on the form of the deposit to an even more marked degree than fissure-veins. The fissures which, in traversing a tough rock, are clean cut, may, in passing into a more easily fractured rock, or one netted by fine jointing, produce a mass of shattered material in which the mineral is so disseminated in minute and numerous fissures that the entire mass must be extracted. Often the vein, solid

and continuous in one rock, splits up, forming horses or drop-pers, or, if very extensive, becomes a zone traversed by many small parallel threads and stringers, too small to be worked. This is discussed by Prof. Beck, in his recent book,* from which Fig. 1 is taken.

In the Guadalupe mine, Chihuahua, Mex., a vein, carrying a solid ore from 10 to 40 feet wide, changes eastward into many small branches, too small to be worked, though the richness of the ore in them may be unchanged.

Where veins traverse foliated rocks, such as gneisses and schists, the original fissures may have been due to a very slight movement along the line of schistosity, and the result may be linked veins, composed of numerous connected lenses, such as are commonly found in the Piedmont area of the Carolinas. If the movement is distributed over several folia the vein is not a simple one, but consists of a series of lenticular masses overlapping each other, and these may occur in a zone; so that the "vein" may be several hundred feet wide.



Section of Level, showing the Florence Vein, Neihart, Mont., crossing an Amphibolyte Dike in Metamorphic Schists.

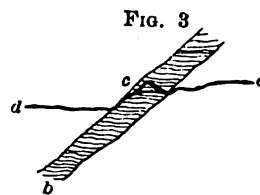
It is evident that, since different rocks break in different ways, the character of the fissures formed in them will depend on the country-rock. Excellent examples of the various effects due to the texture, cleavage, hardness, and other properties of the rocks, are to be seen in the silver-lead mines at Neihart, Montana, where steeply-dipping metamorphic rocks are cut by a large and very irregular intrusion of diorite, and both are cut by later intrusions of rhyolite porphyry. Well-defined fissure-veins cross all these rocks. The metamorphic rocks consist of alternating bands of feldspathic gneiss with softer, more schistose micaceous rocks, and, more rarely, tough amphibolytes. The veins cross these rocks at nearly right angles to the

* *Lehre von den Erzlagerstättenlehre*, Berlin, 1901, p. 135.

schistosity. The underground workings show the veins to vary somewhat in width and in the relative abundance of included rock-fragments, when they pass from one belt of feldspathic gneiss to another, and more markedly when they pass into the more schistose rocks; but the change is so abrupt where the amphibolytes are encountered that the miners say the vein is faulted. In fact, the tough nature of this rock has sometimes deflected the vein, and has always, in the instances observed, narrowed it from 7 to 8 ft. in width of good ore to a foot or more of barren gangue. Fig. 2 shows an example.*

(The same phenomenon is described by De la Beche.† The vein shown in Fig. 3 encounters an elvan dike *b*, in passing from *d* to *e*, and passes up the wall of the dike, scarcely showing as a vein alongside of the dike until it crosses the dike at *c*, and continues on through the slates.)

At Neihart, where the vein passes from schist into Pinto diorite, a peculiar igneous rock of coarse grain and texture, it



Fissure Deflected by Dike (De la Beche.)

invariably narrows, but is well-defined. In the rhyolite porphyry the same fissures lose their compact character, ramifying into a network with shattered rock between, which dissipates the ore; so that, while the surface-workings are commonly rich, the ore-body does not pay in depth, owing to the large amount of waste.

At Butte, Montana, the veins occur in coarse-grained granitic rock (a quartz-monzonite) with intrusions of aphyte granite and dikes of porphyry. Where the veins cross the porphyry they are narrower to a marked degree; and the same is true of the aphyte. In part this is due to a more intense metasomatic replacement of the granite than of the other rocks,—a fact which will be discussed in describing the influence of the wall-rocks on the filling. It is quite evident that the rock-character has influenced the fissure.

* From the 20th Ann. Report of the U. S. Geol. Survey, part iii, p. 421.

† Geological Observer, p. 657.

The copper-veins at Virgilina, Va., which occur in metamorphic schists formed from old igneous rocks, show a structural feature common in the veins of the Southern States where the fissure crosses the rocks at less than ninety degrees to the schistosity. In such cases the veins show many spurs running off for short distances from the vein along the planes of the schist. The Blue Wing mine, at the locality mentioned, shows a diabase dike cutting the schists; and where the vein crosses this rock it is narrowed and becomes a mere zone of plated rock. The spurs seen in some veins in granite are evidently the result of cross-fissures or joints, and not to be considered as a function of the rock itself.

Where the veins pass from schists into quartzite, as may be seen at Neihart, there is a marked change in their character. This is well seen at the Big Seven mine, where a well-defined vein changes to many small fissures with shattered rock between. At Frenchtown, a small settlement east of Deer Lodge, Montana, the veins in andesite-porphry are strong and well-defined fissures, but do not cut any rock; hence direct comparison cannot be made. At the Porphyry Dike mine, south of Rimini, Montana, the veins are small and tight in the granite, and open out in the rhyolite into wide fissures, ill-defined, and really more like bands of shattered rock.

This variation of fissures in different rocks is especially well shown at Cripple Creek, Colo., as described by Penrose,* and alluded to by Van Hise.† In hard rock the fissures are sharp and clean-cut breaks, but in the soft rock they are ordinarily mere series of very small cracks, constituting what Van Hise calls "Distributive" faults.

In slates the vein is commonly well-defined, as at Copperopolis in Montana, and Parral, Mexico. In the Coeur d'Alene in Idaho, the veins cross slates and quartzites, and present only those minor peculiarities which might be expected in passing through such rocks—in fact, there is less change than one would naturally look for.

Throughout the Appalachians the veins show a clustering of quartz-lenses whose ends overlap. These have been called "linked veins" by Becker, and "compression-veins" by Stretch.

* "Mining Geology of Cripple Creek District," by R. A. J. PENROSE, JR., 16th Ann. Rept. U. S. Geol. Surv., 1894-5, part i, p. 144.

† "Some Principles," etc., *Trans.*, xxx., 35.

That they are the result of the foliation of the schists is generally accepted. Where the lenses are parallel to the foliation there is reason to believe that they are a result of the spreading apart of the folia by movement. When the quartz lenticules lie across the vein, as they often do in the Carolinian veins, presenting the structure figured by Rickard* for the Victorian veins, it seems that the quartz-filled spaces result from a rending of the rock between two parallel fissures. Many of the minor peculiarities of vein-walls are due to the character of the rocks, but these are not intended to be treated here. Rickard has already described many features of vein-walls due to varying rocks.

The study of a large number of mines all over the country shows that, although no rule can be laid down for all localities, each district will present certain peculiarities. In Montana, the rhyolites are not favorable for well-defined constant veins, as the rock is too easily shattered. The granular rocks vary in effect; and the more basic forms, carrying augite or hornblende, are favorable for well-defined fissures.

As it is not my intention to do more than call attention to the differences in fissuring in varying rocks, no further mention of such peculiarities will be presented here. It is evident, however, that where a single mass of rock varies in texture, as, for example, the granite core of Castle mountain,† Montana, in which continuous exposures show the rock passing from granite through intermediate gradations into rhyolite-prophyry, the vein-fissures will vary with the physical characters of the rock.

II. INFLUENCE OF COUNTRY-ROCK ON VEIN-FILLING.

Where a vein, passing through two different rocks, carries one set of ore- and gangue-minerals in one rock, and another set in the other, there is a strong presumption that the variation in the enclosing rock has caused the variation in the vein-materials. Similarly, if in given districts one set of vein-minerals always occurs with a certain kind of country-rock, and another set with another kind, it is probable that such association is genetic, and not accidental.

* *Trans.*, xxi., 686-713.

† WREED AND PIRSSON, "Geology of the Castle Mountain Mining District," *Bull.* 159, U. S. G. S.

For many years there has been a widespread belief among mining geologists and engineers that igneous rocks are an almost invariable accompaniment of productive ore-deposits of the precious metals. Whether the igneous rocks be regarded as the actual source of the metal, or as the cause of fissuring and ore deposition by reason of dynamic disturbance, the result is genetically due to the volcanic forces. Prof. Vogt has recently given us, in his able and instructive paper,[†] a *resume* of his studies, and Prof. Kemp has shown[‡] both the competency of the igneous rocks themselves as a source of supply and of the intrusives as a source of energy. It is not this phase of the subject that I propose to discuss, but the time-honored question of the influence of wall-rock upon the mineral contents of the vein. Many students of ore-deposits, familiar with the common occurrence of galena-ores in limestone, and the changes in mineral character of the Cornish veins with change of rock have sought to establish a relation between certain rocks and certain ores. While such a condition seems to prevail in a few districts, no general law has been established by these attempts.

Conditions Governing the Relation of Country-Rock to Vein-Contents.

In considering the relations between country-rock and vein-contents, the following premises are assumed:

1. Vein-filling may be the result of (*a*) the filling of open fissures, (*b*) of replacement, or (*c*) of both filling and replacement.

2. The ore- and gangue-minerals of all these types vary. Lindgren has divided veins filled by metasomatic replacement into eleven classes, and shows that the chemical processes involved were very different in each case. It is made certain by the study of altered wall-rocks and of mine-waters that the mineral-forming solutions have varied greatly in character. Moreover some veins have been opened after formation, and new minerals have been introduced by later solutions.

In veins the material of which is well crustified, or is known to be the result of the filling of open fissures, a marked influence of the wall-rock on the contents of the vein would

[†] "Problems in the Geology of Ore-Deposits," *Trans.*, xxxi., 125.

[‡] "Role of the Igneous Rocks," etc., *Trans.*, xxxi., 169.

not be expected. In the majority of veins, however, there is evidence of more or less metasomatic replacement; and it is evident that the nature of the wall-rock will be an important factor in the chemical reactions of the processes of replacement. It should be remembered, however, that the evidence of many districts shows that veins of different kinds and ages may form in the same rock, and hence it is not to be expected that any general conclusions, applicable to all veins, can ever be reached.

Examples.

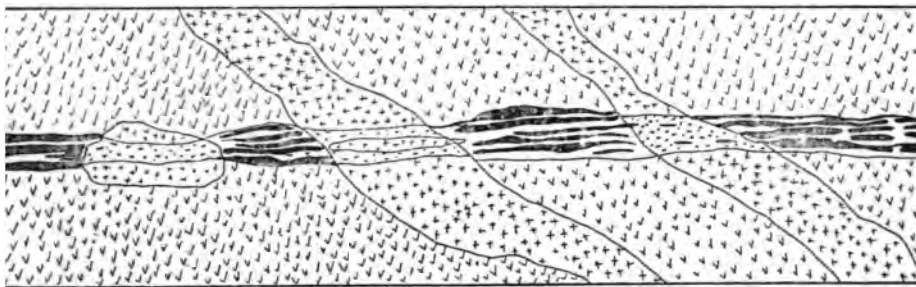
Butte, Montana.—In the typical silver-veins of this district the filling consists of quartz, showing well-marked “comb”-structure, with rhodonite, rhodochrosite, pyrite, zinc-blende and silver sulphides. The structure is clearly that of the filling of open fissures. These veins occur in the normal Butte granite, a quartz-monzonite, and in the Bluebird granite, which is an aphyte. There is, however, no perceptible difference in either the character or the tenor of the ore between the veins in the aphyte and those in the normal granite, or in the parts of the same vein where it cuts the two rocks. In the copper-veins on the other hand, there is a marked difference. These are of undoubted metasomatic origin, and were formed by the replacement of the rock along fracture-planes. In the copper-area, the veins cut both the two rocks previously mentioned and also a quartz-porphyry, which I have named the Modoc porphyry. In the Butte granite, the veins are commonly rich in copper; in the Bluebird granite they are almost equally wide and strong, but are lean, and composed chiefly of quartz, with comparatively little pyrite and copper. In the porphyry, the veins are narrow and lean. There are so many instances in which the same veins can be seen cutting all three rocks that there can be no doubt as to the correctness of these conclusions. The vein-filling consists of quartz which shows no comb-structure, with pyrite and various copper-minerals, of which chalcocite, enargite and bornite are the most common. The walls on each side are much altered, and the less altered rocks at some distance from the veins show the ferromagnesian silicates altered to pyrite. The relative richness of the veins in the Butte granite is believed to be due to the basic character of the rock, and its greater content of the easily replaceable iron silicates. The rock is a quartz-monzonite, the compo-

sition* of which has been carefully calculated from chemical analyses of the rock, and of the biotite and hornblende isolated from it, and from microscopic analysis of the rock as well.*

This shows it to contain 15.26 per cent. of hornblende and 4.22 of biotite. There is a little augite also. The aplyte contains over 10 per cent. more silica than the rock just noted, no hornblende, and very little biotite. The Modoc porphyry also has, when fresh, a very little mica, and is high in silica as the aplyte. Mr. H. V. Winchell has called my attention to the condition shown in the diagram, Fig. 4. In the case here given as a general type, the vein is workable only in the Butte granite.

A study of thin sections of the rock adjacent to the ore shows that the hornblende is the first mineral to be altered into ore, and that the bunches of this mineral form the nucleus

FIG. 4



 Granite
  Aplyte
  Quartz

Ideal Plan of Conditions in a Copper-vein at Lutte, Mont., passing from Basic Granite into Aplyte Masses.

for a more or less complete replacement of the entire rock. The general principles of this metasomatic replacement are those given by Lindgren.† It is probable that the alteration now seen in the wall-rock with its nests of pyrite replacing the biotite and the hornblende, may present the earlier stages of the metasomatic process, and that the pyrite thus formed was not only the nucleus for a further deposition of pyrite, but that the pyrite itself was the precipitating agent for the copper-minerals, as has been shown to be the case in the secondary enriched ores. In the aplyte there is more quartz and less

* "Granite Rocks of Butte, Mont." W. H. WREED, *Jour. Geol.*, April, 1900.

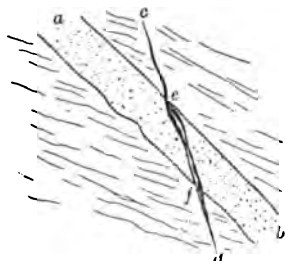
† "Metasomatic Process in Fissure-Veins." *Trans.*, xxx., 578.

pyrite, and the latter mineral is noticeably poor in copper: The same general statement also holds true for the porphyry.

The Dolcoath mine of Cornwall is perhaps the best-known example of a vein, the mineral contents of which vary with the nature of the enclosing rocks. As described by many writers, the veins carry copper-ores in slate and tin-ores in granite. Stretch* gives a further example of argentiferous galena with its usual associated blende and pyrite in a decomposed plagioclase porphyry, changing to auriferous arsenopyrite in the underlying granite.

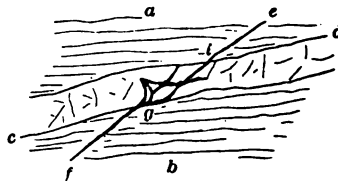
Cornwall.—Fissures crossing the contact of granite or other intrusive rock with sedimentary rocks are not uncom-

FIG. 5



Section across Wheal Alfred Gwinear Cornwall. Rich ore occurs in the Dike only. (From De la Beche.)

FIG. 6



Vein Split in Traversing Jointed "Elvan" Dike (De la Beche.)

monly productive, when the district is metalliferous. This is very marked in the Cornwall mines, where bunches of ore occur at the junction of granite and schist. De la Beche† mentions fissures traversing schists and passing through a dike of porphyry (elvan) some 300 ft. thick. The vein above the dike carried little ore; in the elvan, ore was abundant and rich, but became poor again in the slates beneath (Fig. 5). This occurrence of ore-bunches where fissure-veins cross such dikes has always been known to the Cornish miners. When the lodes pass into the dikes, they are often branched and split, as shown in Figs. 3 and 6 (after De la Beche); and in such cases, though the total amount and richness of ore be the same, the vein may not pay to work, on account of the large amount of waste.

* "Prospecting, Locating, and Valuing Mines," p. 135.

† *Geol. Observer*, p. 678.

Pontgibaud, France.—Here the silver-lead veins occur along fractures within granulyte dikes, and on the line of contact with the gneiss country.

"When the dike diminishes in size the vein decreases in width; when the vein penetrates the gneiss the ore disappears. The best ore is associated with the kaolinization of the feldspar of the granulyte; when the latter becomes hard, unaltered in depth, the ore pinches out."*

Rico, Colorado.—Rickard also mentions the veins of rich gold- and silver-ores at Newman Hill, Rico, Colo., as "noticeably affected by the character of their rock-walls." There is a marked change in passing from limestone into sandstone; and generally the veins are richest in the darker-colored sedimentary rocks. The interdependence between country-rock and ore is briefly discussed by Rickard, who adopts Cotta's explanation that the physical texture and chemical composition of the country-rock affect the deposition of ore, and declares that it was undoubtedly the carbonaceous matter of the rock at Rico which acted as precipitant. This example differs, therefore, from that of Pontgibaud, where feldspar has been replaced by silver-bearing galena.

Neihart, Montana.—At this locality the veins show remarkable variation in richness, corresponding to differences in the

FIG. 1

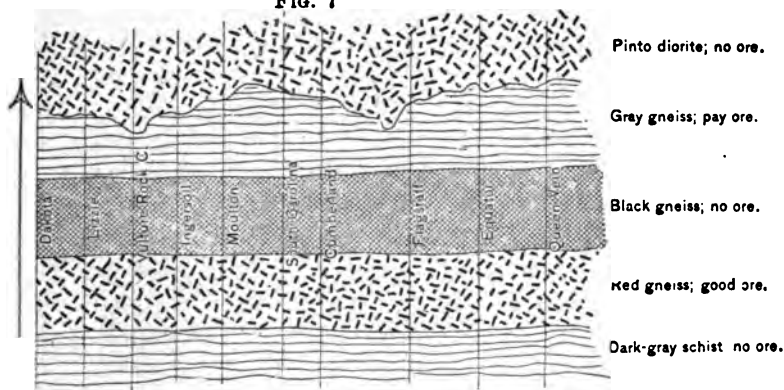


Diagram (Plan) Showing Rocks Traversed by the Neihart Veins, and Relation of Pay-Ore to Country-Rock. (The veins are indicated by simple parallel lines.)

wall-rock. Mr. Robert H. Raymond, the former manager of the Diamond R. properties, found that the veins were barren

* T. A. RICKARD, "Vein Walls," *Trans.*, xxvi, 200 (1897.)

in the dark-colored gneisses, and held ore-bodies in the pink or white feldspathic gneiss. My own observations enabled me to confirm this in a general way, and also showed that in amphibolyte the vein was barren as well as narrow, and that no workable ore-bodies had been found in the diorite. In quartzite and in the intrusive rhyolite porphyry the veins have proved rich near the surface, but the values have gone down but a few yards. It is believed, however, that this is because of structural conditions, with secondary enrichment of a shattered zone, rather than because of a mineralogical condition due to the nature of the enclosing rock. These conditions are indicated in Fig. 7, reproduced from my report on the district.*

Furstenburg.—A similar example is quoted from Fournet by De la Beche.† The Wenzal vein at Furstenburg is nearly vertical and cuts down through many beds of gneiss, about 60 ft. thick, that dip east. In the micaceous gneiss the vein is a nearly imperceptible string of clay. In argillaceous slates it suddenly becomes 12 to 18 in. thick, consisting of baryta, ruby-silver, large masses of antimonial silver, and argentiferous copper. In the hornblende-gneiss it continues, but the silver-ores are wanting and galena is the only ore. In the fourth series, of slightly micaceous beds of gneiss, the silver-ores are as abundant as in the argillaceous slates; but they gradually disappear in depth, being replaced by selenite and galena.

It will be noted that the Neihart veins present several contradictions to the rule observed in the Butte district. The ores occur in the feldspathic rocks, carrying little ferro-magnesian minerals. The basic amphibolyte and the diorite are both barren. It should be noticed also, in this connection, that the ore-depositing solutions were markedly different in the two cases. In the Neihart veins the gangue is mainly a mixture of carbonates of lime, iron and manganese. The ores are also markedly different, as they consist primarily of galena with sphalerite and pyrite, which is secondarily enriched in the upper parts of some veins. The solutions have been of such a character as to react with the feldspars rather than with the ferro-magnesian silicates.

Other Montana Localities.—In the silver-lead camp of Barker in the Little Belt Mts., near Neihart, as at the mines

*"Geology of the Little Belt Mts., Mont.," 20th Ann. Rept. U. S. Geol. Surv., 1900. Part iii, p. 419.

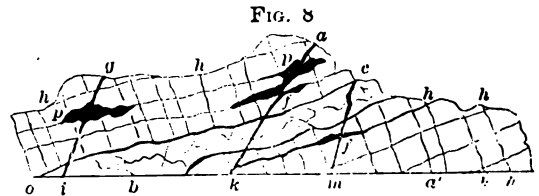
† *Geological Observer*, p. 680

at Castle, Mont., and a score of other places where the ores occur in limestone, it is evident that different action has taken place. Here, as is so very commonly the case, the ore-bodies occur in limestone near the contact of the igneous intrusions. The heat of the latter and the vapors of the cooling magma have altered these limestones to more or less coarse-grained marbles, if the limestones were pure, or to mixtures of garnet, epidote and other silicates, if the limestones were impure. The latter is the case at the Trout mine and other contact ore-bodies near Phillipsburg, Montana, where the Granite Mountain vein (of quite different and drier ore, without lead) occurs in the granite. In this case the gangue is largely silica; and it is probable that similar solutions circulating as a result of the heat supplied by the igneous intrusion, and, in part, at least, in fissures formed in rocks by the intrusion, formed one set of ores in the limestone and another in the granite.

Another instance of the difference of mineral contents in the same ore-deposit in different rocks is shown by the Elkhorn mine at the town of that name, Jefferson county, Montana. This deposit is peculiar in its structural relations, being similar to the well-known saddle-reefs of Australia in that it occurs in the saddleshaped mass along the axis of a steeply pitching anticlinal fold. The rocks are sedimentary, of probable Cambrian age, and dip at steep angles toward the contact of a great mass of granite and other intrusive igneous rocks. The ore occurs at the contact between an altered shale and a massive crystalline limestone, and both rocks have been changed by contact metamorphism. The bedding-plane is ore-bearing only where the general dip of the rocks is disturbed by flexures. In addition to the ore found along the contact, a number of very large ore-bodies have been found at some little distance in the dolomite, though always in the same structural position. The ore found along the altered shale-dolomite contact is essentially a "dry" quartzose milling-ore; that of the dolomite, mainly galena, with accessory sphalerite and pyrite. Both ores are connected by "pipes" and stringers, and both the field and the microscopic evidence shows that they were formed by the same solutions and at the same time. There is no escape from the conclusion that the difference in the mineralogical character of the ores is the result of the different nature of the enclosing rock.

It would be tedious to enumerate all the familiar deposits in limestone. Those of Leadville, Colorado, and Eureka, Nevada, have been thoroughly studied and described. Tombstone, Arizona, presents quartzose veins filling fault-fissures, cutting slightly tilted sedimentary rocks, with the workable ore-bodies formed by replacement of limestone along bedding-planes, and presumably by the same solutions that filled the fissures.

Derbyshire.—The Derbyshire lead-mines of England are also well-known examples of veins carrying galena in limestone, and barren when in the intercalated intrusive trap-rocks (toadstone.) Fig. 8, from De la Beche, illustrates the occurrence of galena in the limestones above and below an intrusive sheet in one of the Derbyshire mines. The leader or fissure traverses the "toadstone" as well as the lime-rock, but it is only in the limestone that galena occurs in the altered area. The channels or rakes (*g i, d k, c m,*) were fissures, through which solutions reach the pipes or ore-bunches *p p*, the bedding-plane deposits *f f*, and the joint deposits *h h*.



Limestone Beds of Derbyshire, with Intercalated Beds of Igneous Rock (Toadstone) Traversed by Veins. (De la Beche.)

Contact-Deposits.

As Lindgren has remarked in discussing the formation of contact-deposits, a chemical reaction seems to take place between the substances leaving the magma and the carbonate of lime, causing the deposition of new minerals and the liberation of carbon dioxide. In the cases mentioned in this paper, the evidence shows that the veins were probably formed, not by true pneumatolitic action, but by hot circulating waters which were as truly a result of the igneous intrusion as the vapors and gases of pneumatolitic action. The escaping vapors and gases from the magma were, it is believed, taken up by circulating waters of either deep-seated or meteoric origin, so that the "mineralizing agents" which had taken up and formed the

volatile compound of various metals, as supposed by Lindgren, passed into solution. Concerning the occurrence of this class of deposits in limestone, Mr. Emmons's description of the Greenwood ore is quite significant. He says: "The ore-bodies are cut by eruptive dikes that do not apparently disturb or exert any *metamorphic influence on the ore*, and yet are not at all mineralized themselves." At a number of localities seen by the writer, the veins, if traced into the granite or diorite, would be found to be barren of galena, and generally without value. On the other hand, at Marysville, Montana, the veins show no appreciable change in character in passing through the altered shales or hornstones into the granite. It should be noted, however, that the ores at this place are not lead-bearing. Moreover, I am told by Mr. G. H. Robinson, the former manager of the mine, that in the earlier workings the veins showed a marked tendency to be richer in approaching the granite (or rather diorite) contact, and were poor when they passed into the granite.

Thunder Bay Silver-Veins.—Mr. H. V. Winchell tells me that the Thunder Bay district of Canada affords excellent examples of vein-variation in different rocks. The basaltic caps and sills of that region overlie Animikie slates and argillites, resting in turn upon taconytes and several hundred feet of cherts. These rocks rest upon the basal quartzite overlying the Archean complex. The silver-veins are often from 8 to 10 ft. wide in the slates, and carry native silver and argentite with small amounts of blende, galena and pyrite, in gangue of quartz, barite, calcite, fluorite, etc. They are wide and productive in the slates, but split up into narrow and barren seams in the overlying trap-rock, and are barren in the underlying cherts and Archean rocks. The Rabbit, Silver Mountain, Beaver and other mines have been noted producers.

Kemp* describes the Silver Islet mine as a fissure-vein carrying native silver, argentite, tetrahedrite, galena, blende and nickel and cobalt compounds in a calcite gangue. The vein is in flags and shales of the Animikie series (Algonkian) and cuts a large trap-dike (gabbro), *within which alone the vein is productive.*

* "Ore Deposits," 3d ed., 1900, p. 283.

Influence of Carbonaceous Matter on the Formation of Ore.

The well-known reducing action of carbon has long been an accepted explanation of the occurrence of ore-bodies in carbonaceous shales. The silver-veins of the Animikie slate are often cited as examples. The Australian veins, which carry rich gold-ores only where they cross "indicators," are a well-known instance, and the *Fahlbands* of Norway another. Rickard ascribes the Australian ore-bodies to the reducing action of the carbonaceous shales. All the descriptions show, however, that although these indicator-reefs are strata of carbonaceous shale, they are remarkable for the amount of pyrite they contain, while other shale-beds crossed by the veins are also carbonaceous, but not pyritic. In previously published papers I have called attention to the reducing action of pyrite on solutions carrying copper-salts; and believe that this mineral is the real precipitating agent in both the Australian and Norwegian ores cited. This view, based upon field-observations and laboratory experiments, in connection with the work of the U. S. Geological Survey, is strengthened by the experiments made under the direction of my friend, Mr. H. V. Winchell, geologist of the Anaconda Copper Co., who finds that the mine-waters of that company's properties, though strongly charged with cupric sulphate and ferric sulphate, also contain large amounts of carbonaceous matter from the old mine-timbers. It is evident that if the carbon were an active reducing agent, it would reduce the ferric iron to the ferrous condition. On the other hand, experiments show that pyrite from the Butte veins left for several weeks in the natural mine-waters became coated with copper-glance (Cu_2S).

*Dependence of Vein-Minerals on the Character of Wall-Rock,
Due to Metasomatic Chemical Reactions.*

The examples given show that a variation of mineral contents coincides with the change of country-rock in many places and in many kinds of veins. A study of the vein- and gangue-minerals and of the rock contiguous to the orebearing fissures is therefore essential to a complete understanding of the origin of ore-deposits. The rocks forming the vein-walls are commonly altered. Where no such alteration is observable, it will usually be found that the veins are the result of the filling of cavities, and are thus excluded from the category discussed in

this paper. Nevertheless, some metasomatic alteration of the rock adjacent to the fissure is usually present; and it must be admitted that many veins show evidence both of the filling of open cavities and of deposition by replacement.

As already indicated, the coincident variation of mineral contents and wall-rock is due to metasomatic action, whereby there is a chemical interchange between the rock and the vein-producing solutions. The metasomatic process varies greatly because the solutions vary. Lindgren* has treated the subject fully, and has indicated the chemistry of the process, so that a detailed account of the reactions involved is unnecessary here. According to his clear demonstration, the alteration of the same kind of wall-rock shows that the vein-forming solutions have varied greatly in their chemical effect upon vein-contents, even where the veins are of metasomatic origin.

The most frequent process seems to be, in granitic rocks, a reaction between the ferromagnesian minerals, such as augite, hornblende, biotite, etc., and the vein-forming solutions, with the formation of pyrites and other sulphides. If later reconcentration occurs, bonanzas are formed by reaction of the pyrites on later solutions. This process I have treated quite fully in a monograph now in preparation on the Butte ore-deposits.

In other cases the feldspars are attacked, and the iron minerals of the rock are not *replaced*. Such a case is described by R. C. Hills;† and Rickard ascribes the silver-lead ores of Pontgibaud, France, to the replacement of the feldspars of granulyte, as already quoted.

The attempt to tabulate the relation between vein-contents and country-rock has been made by various writers, and lately by Stretch. The latter author, in his very interesting essay,‡ has given 139 occurrences, and attempted to eliminate the personal equation of the observer. It is evident, however, that existing literature is not adequate for such work. Too often the rocks are wrongly named, or receive generic terms only. The words "granite" and "porphyry" have long been used in a textual sense by mining engineers, and by many geologists

* "Metasomatic Processes in Fissure Veins," *Trans.*, xxx., 578.

† *Proc. Colo. Sci. Soc.*, vol. i., p. 20.

‡ *Pocketbook for Prospecting, Locating, and Valuing Mines*, Sci. Pub. Co., N. Y., 1900.

unfamiliar with petrographic distinctions; and, as is well known, shales, limestones and sandstones grade into one another. For the careful study of metasomatic replacement, which must be made to establish scientifically a relation between country-rock and vein-filling, finer distinctions must be made. The granitic rocks of some writers include gabbros, diorites, granite and aphyte, with a wide range of mineral and chemical compositions. The most that can be attempted at present is to present the known facts of occurrence in deposits about which there can be no doubt, or which have been carefully studied. The facts here set forth show the advantages of geological examination of the district about a mine, especially of the area containing the vein. It is evident that it is important to ascertain the extent laterally and the probable extent vertically of the rock in which the ore occurs; and, if other rocks occur, what they are and what effect, if any, they will have on the vein-fissure and vein-filling. Such associations have long been recognized in a rough way by the miners, who say "that mineral will not live long in such a rock." The instances noted in the literature of ore-deposits are few, compared to those actually encountered in mining operations, where the character of the vein has changed in depth. Such change is, it is true, very often due to secondary alteration, with or without reconcentration and enrichment of material, but in many cases it is probably due to change of rock.

CONCLUSIONS.

From the evidence presented the following conclusions are drawn:

1. The structural characters of vein-fissures, such as course, width, etc., vary with the nature of the country-rock.
2. The mineral contents of veins formed wholly by the filling of open fissures are not affected by the nature of the vein-walls.
3. The mineral contents of ore-deposits formed by metasomatic replacement vary with the nature of the enclosing rock.
4. As metasomatic processes vary in character with the nature of the solutions, no invariable general relation can be established between certain rock-types and rich ore-deposits.

EDITORIAL COMMENT.

THE LANSING SKELETON.

The article of Mr. Upham in this number of the *Geologist* sufficiently details the facts relating to the topography and other surroundings of the place in which this skeleton was found. It may be well to mention however, more in detail, some facts relating to the skeleton itself, and to the act of discovery.

The tunnel in the excavation of which the skeleton was found was commenced in the winter of 1900 and 1901, and was about half completed that winter. It was resumed and completed in the winter of 1901-1902. The human skeleton was found in February, 1902, at the distance of about 70 feet from the mouth of the tunnel and about 20 feet below the natural surface.

The men are farmers and did not appreciate the significance of the discovery, breaking the skull with the pick and scattering the pieces with the rest of the skeleton, hardly taking pains to throw the fragments into a place by themselves. Mr. M. C. Long and Mr. Butts, both of Kansas City, endeavored to secure the remains, and Mr. Butts purchased from the owner for a dollar and a half, the right to the lot, but a compromise was effected by which Mr. Long received the fragments of the skull and Mr. Butts received the rest. Mr. Long was instrumental in bringing the skeleton to public notice and Prof. Williston's article in *Science*, Aug. 1, 1902, was the first accurate and trustworthy account. It is plain, therefore, that the circumstances of the initial history do not suggest any collusion or attempt to deceive the public.

The owners of the farm were subjected to close questioning. It should be stated that after the close of the examination of the spot, in the presence of the owners, there rested on the minds of the four experienced scientists present and participating not a shadow of doubt as to the veracity of the farmers Concannon. Some of the party (including the writer) inspecting the wall of the tunnel with a small pick, about sixty feet from the entrance, for the purpose of learning its character and alternations, found small bits of black charcoal near the top and two small fragments of bone adherent in the wall,

near the floor of the tunnel. Others found fragments, by pulling over the dump heap at the mouth of the tunnel.

The material penetrated by the tunnel is common loess, but throughout its lowest, 2 to 4 feet, it is very irregular. It here shows no evidence of water stratification. It is charged with rotting fragments and slabs of the limestone of the region, but contains no foreign drift. Over this mass of non-stratified material is a thickness of two or three feet of distinctly stratified loess. The evidences of water stratification become less and less distinct toward the roof of the tunnel, but there is no abrupt change in texture from the bottom of the stratified portion to the roof of the tunnel. It appears reasonable to suppose that at first the entire mass of loess was stratified, and that by the action of atmospheric forces, including vegetation, the stratified structure has been destroyed in the upper portion. It was probably deposited by the Missouri river at a former high stage and cannot be distinguished from the great loess sheet of that valley at Kansas City. The skeleton was found, not in this alluvial loess deposit, but in the unstratified debris amongst the limestone fragments that lie below it. It is hence pre-loessian but probably not much older than the loess, since, if it had been long exposed near the natural surface prior to being covered by the loess, the skeleton would probably have been so disintegrated that the bones would not bear their own weight. The material in which the skeleton lay was apparently the sliding and rotting limestone debris that accumulates on all limestone bluffs, and which is seen along the river bluffs at the present time where the railroad skirts them and the grade occasionally cuts into them.

Professor Williston has kindly furnished the following memorandum of the skeleton:

The preserved portions include the larger part of the skeleton:—the skull, various vertebrae, humeri, radius, carpal and finger bones, pelvic bones, femora, tibiae, fibulae, tarsal and toe bones. The femora measure seventeen and a half inches in length, indicating a person of average size. The pelvic bones have not been mended so that the sex can be determined. The skull does not appear to be much if any below the average size; it is distinctly dolichocephalic, the forehead receding, with the orbital margins prominent, and showing especially prominent supraciliary ridges. The complete mandible has lost on each side the first and second molars, with absorption of the alveolar processes. All the other teeth are worn to a remarkable degree, the third molars or

wisdom teeth are large with the crowns worn more than half way down, smoothly and with the surface inwardly oblique. The incisors, canine and premolars also show the same extreme wear with the inner, or buccal surface worn away deeply. Three teeth and three alveolæ are preserved in the maxillary bone, all the teeth much worn except the second molar which was above the diastema left by the loss of the molars below. This tooth shows little or no trace of wear, indicating the loss of the lower molars at a time long prior to the death of the individual. There is no indication of the ridges above the genial tubercles on the inner side of the mandible in front, said to be characteristic of the *Homo neanderthalensis*. The cranium has a remarkable resemblance to one of a mound-builder recovered from a mound near Kansas City some years ago. The two halves of the mandible appear to have been broken in two either at the time of death or afterwards, as they were found separated, if the testimony of the finders is to be relied upon; their extremities also indicate an original separation of the parts by the hard matrix attached to them.

Prof. Williston also writes, Aug. 26: From a recent examination of the Lansing bones I find that they belong to a female between five feet two inches and five feet four inches in height. They are unusually small, even for a female; the forearm is unusually long; the pelvis not very broad. The woman was not less than forty years of age.

Again Prof. Williston writes, August 31, 1902: A further and careful examination of the bones of the "Lansing skeleton" proves conclusively that there are two skeletons. The jaw found at a distance (as I understand) is that of a child about 10 or 11 years of age, as is shown by the presence of uncut canine tooth and of a deciduous molar. Please, therefore, correct my statement previously sent that the upper first molar showed little wear,—thus indicating the removal of the lower molars at a much earlier time. This jaw (the upper) belongs to the child.

It was noticeable that there is some irregularity in the size of the teeth, viz.: the canine teeth are small, resembling incisors, and are followed, backward, by two similar incisor-like teeth in place of distinct bicuspid.

The important question lies in the age of the loess covering the skeleton—was it of the high-water stage of the Wisconsin epoch, or of the Iowan? There was not sufficient time at hand to enable the party to go into a thorough examination of the valley with a view to determining the question with certainty. There is not, in the immediate vicinity any sufficient evidence of the existence of terraces, whether of residuary or constructional origin, along that part of the great valley; but at Council Bluffs, in Iowa, north of the city, is a distinct rem-

nant of a terrace rising about 125 feet above the river, the contents of which are loess, but at the base becoming too sandy and coarse to warrant that name. Again, between Council Bluffs and Sioux City, as mentioned by Mr. Upham, another terrace about 20 feet above the river borders the river on the east side for many miles. The Missouri Valley Railroad is located on it. There is at hand no evidence as to the nature of this lower bench—whether it consists of drift materials or of rock, and if of the former whether it is a residuum of the general loess sheet due to a halting shrinkage of the Missouri from its loessian stage or to a construal refilling subsequent to its deeper excavation. Mr. Upham regards it, at least in a tentative manner, as a constructional terrace of later date than the general loess, and probably due to the high waters of the Wisconsin ice-sheet then existing further north. In the absence of knowledge of the nature of these terraces, either or both of which may have once existed at Lansing and at the Concannon farm, the only recourse is to accept the determinations and classification of the Iowan geologists as to the origin and date of the loess covering the tomb of the Lansing man.

The general loess sheet of the Missouri valley, in western Iowa and in northwestern Missouri, and in the adjacent portions of Nebraska and Kansas, presents such uniformity of character that it seems necessary to ascribe it to a single cause and apparently to the same date. Still Prof. J. E. Todd has suggested that* it is divisible into two parts: an upper loess covering the uplands, and a lower loess restricted to the valley of the river, the latter being much the younger and forming a terrace which rises about 125 to 150 feet above the present level of the river. Such terrace has already been mentioned at Council Bluffs. It is indicated on the Omaha side of the river, viewed from Council Bluffs, by the jog in the distinctness of the timber line. This terrace must have extended to Lansing and its relative date, as compared with the upland loess, plays an important part in the question of the age of the loess overlying the skeleton.

In any case, accepting the determinations of the geologists of Iowa, and the time-ratios of Prof. Chamberlin, the loess of the river at Lansing can be no more recent than the date of

* *Missouri Geological Survey*, vol. x, p. 128.

the Iowan ice-epoch, and that would make it five times the period elapsed since the final retirement of the ice. Post-glacial time has been computed in various ways, and it has been pretty nearly unanimously agreed that post-glacial time does not exceed 10,000 years, and probably amounts to about 8,000 years. Accepting the lower term, the age of the Lansing man is found to be near 40,000 years. These time-ratios, however, are tentative, as given by Chamberlin, and may require considerable modification.

From a study of the interglacial gorge running through the west part of the city of Minneapolis, the writer calculated that about 15,000 years were required for its excavation by the Mississippi river.* It was supposed to have been formed immediately prior to the Wisconsin epoch and after the Iowan. On that supposition the close of the Iowan epoch was approximately 23,000 years ago. If 8,000 years be added to this for the duration of the Iowan (which is probably too small an allowance) the commencement of that epoch, which may be assumed to be about cœval with the Lansing skeleton, was about 31,000 years ago. If, however, the interglacial Mississippi gorge at Minneapolis was excavated at some earlier interglacial epoch, say the Buchanan (pre-Iowan) or the Aftonian (as suggested by Mr. Upham) it antedates the Iowan loess, and cannot serve as a factor in any calculation as to the age of the Lansing skeleton.

It will require, therefore, considerable further and careful examination of the loess sheets of Iowa, and of their relations to the till-sheets, as well as the marginal features of the till-sheets themselves, to enable anyone to fix with any certainty the age of the Lansing skeleton more exactly than is above indicated. That it dates from glacial time, at some remote point in the complex history of that age, is about all that can be affirmed from the present state of knowledge of the drift deposits.

It remains to call attention to a newspaper story which affirms that formerly a cemetery of the Fort Leavenworth penitentiary was located at or near this place, and that the skeleton is but one of numerous others that could probably be found in the immediate vicinity if sufficient exploration should be under-

* An approximate interglacial chronometer, *AM. GEOL.*, vol. x, p. 69 and 302, 1892.

taken. It is not at all likely that the four geologists who made the recent joint examination, and who are supposed to be expert in the detection of all irregularities in the ground and all such variations that would be implied in the existence of a modern burial at this place, would have failed to observe the disturbance which such a burial would have produced. Again, on the authority of Mr. Long it appears that such former burial place was at a distance of three miles from the place at which this skeleton was found.

Still the same imputation can be brought against this skeleton as against numerous other alleged human relics discovered in glacial or pre-glacial deposits, viz.: no scientist was present at the time of discovery to vouch for the fact and to verify the place and the surroundings of the skeleton. N. H. W.

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CORRESPONDENCE.

THE NEW MADRID EARTHQUAKE. In his valuable and instructive article on "The New Madrid Earthquake" in your current number, professor Broadhead makes no reference to a source of information which I have regarded as of first importance, viz: Mitchill's article in "Transactions. of the Literary and Philosophical Society of New York," Vol 1, 1815, pp. 281-307. The full title of the article is, "A detailed Narrative of the Earthquakes which occurred on the 16th day of December, 1811, and agitated the parts of America that lie between the Atlantic Ocean and Louisiana; and also a particular account of the other quakings of the earth occasionally felt from time to time to the 23d and 30th of January, and the 7th and 16th of February, 1812, and subsequently to the 18th of December, 1813, and which shook the country from Detroit and the Lakes to New Orleans and the Gulf of Mexico. Compiled chiefly at Washington, in the District of Columbia. By Samuel L. Mitchill, Representative in Congress, etc. (Read before the Society on the 14th of April, and the 12th of May, 1814.)" Briefer articles on then recent earthquakes in Venezuela, on the volcano and earthquake in the island of St. Vincent, on volcanoes in the Azores, and on the atmospheric disturbances accompanying the New Madrid earthquake, are appended on the ensuing pages 308-340.

Dr. Mitchill's article is by far the fullest contemporary account known to me. It is rendered especially valuable by the full and explicit data relating to the earthquake in its eastern extension. From the data it appears that the primary shock of December 16, 1811, was destructive at Charleston and many other points in South Carolina, at Richmond and elsewhere in Virginia, at Washington, at Fort Duquesne (Pittsburg), at Detroit, at Fort Dearborn (Chicago), and at many other points so distributed as to indicate that the area affected by the earthquake must have reached at least a million and a quarter square miles, or some two-fifths of the present area of the United States. He introduced many original records not elsewhere published; among others a letter from William Shaler, Esq., kinsman of the distinguished geologist of Harvard, who was descending the Mississippi in a flat-boat when the subsequent shock of February 7, 1812, occurred and whose craft was caught and floated up-stream "with the velocity of the swiftest horse."

Another contemporary record of value was that of Engineer Louis Bringier, published in an early number of the American Journal of Science, whose name is misprinted "Binegler" in professor Broadhead's article (p. 83); and it is of interest to note that Dekay's type of *Bos pallasi* (now *Oxibos catifrons*) was founded on a skull thrown out of one of the earth fissures formed during the New Madrid disturbance. My own information relating to the earthquake was originally derived from a manuscript diary, or ordinary book, kept by a grandfather residing in Barren county, Kentucky, during the period

1811-1813, where the disturbances were severe and often destructive. Unfortunately this record is no longer in existence.

It was my fortune in 1891 to traverse a considerable part of what may be called the epicentral area of the New Madrid earthquake, and to trace certain of its geographic and other effects. These include fissures in both bluffs and bottom-lands, those in the bluffs being simple chasms generally cleaving ridges or paralleling scarps, and still remaining open sometimes to depths of three to five feet; while the fissures in the bottom-lands are usually marked by banks of gravel erupted from earlier Columbia deposits beneath the Port Hudson clays, some of these gravel banks being fifty to one hundred feet wide, hundreds of yards long, and three to ten feet high. Still more striking, of course, are Reelfoot lake, east of the river, and the "sunk country," which replaces a river system (Whitewater) on the west; but to my mind the most impressive phenomenon of all is the lifted country lying athwart the valley of the great river a few miles below New Madrid. This area may be likened to a low elliptical dome, springing from the western shore of Reelfoot lake and the eastern border of the sunk country; it measures some twenty miles in width from east to west, and thirty or forty miles in transverse diameter; its height, estimated from the elevation above the river in comparison with the height of banks above and below, may be twenty or twenty-five feet. The various phenomena still traceable on the ground have been repeatedly described in lectures; and an abstract of one of these, under the title "A Fossil Earthquake," was published in *Bull. Geol. Soc. Am.*, Vol. 4, 1892, pp. 411-414.

W. J. McGEE.

Washington, D. C., Aug. 14, 1902.

PERSONAL AND SCIENTIFIC NEWS.

MR. H. O. WOOD has been appointed assistant in mineralogy and petrography at Harvard University for the coming academic year.

MR. T. T. READ, E. M. ('02 School of Mines, Columbia University) has been appointed instructor in mining and metallurgy in the University of Wyoming.

MR. WM. C. PHALEN, M. S., of Gloucester, Mass., has been appointed an aid in the Department of Geology in the U. S. National Museum at Washington. Mr. Phalen is a graduate of the Massachusetts Institute of Technology and was for two years engaged in teaching in the School of Mines, Socorro, New Mexico. He comes to the Museum under the civil service regulations, and will have immediate charge of the petrographic collections.

WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY. Dr. Samuel Weidman, assisted by Mr. W. D. Smith, is engaged in mapping a district in the north central part of the state. The rocks of this area are of Pre-Cambrian and Cambrian age,

the former consisting of granites, gneisses, nepheline syenites, quartzites and slates, and the latter of Potsdam sandstone. The district is crossed by the boundary of the driftless area and Dr. Weidman has been able to differentiate several drift deposits lying outside of, and earlier than, the terminal moraine of late Wisconsin age. It is hoped that a report on this district in the north central part of the state, to be issued as a bulletin of the Survey, will be ready within a year. In the meantime a report on the soils of the district is being prepared for the Annual Report (for 1902) of the State Board of Agriculture.

Dr. E. R. Buckley, now state geologist of Missouri, began the preparation of a report on the road materials of Wisconsin while connected with the Wisconsin Survey, and it is expected that this report will be issued shortly.

Professor N. M. Fenniman, of the University of Colorado, has prepared a report on the lakes of Wisconsin and their physiographic features, which is now in press.

Professor U. S. Grant, of Northwestern University, is engaged in a study of the lead and zinc deposits of the southwestern part of the state, where there is a revival of mining interest. A preliminary report on these deposits will be prepared during the coming fall and winter.

COLUMBIA UNIVERSITY NOTES: Professor J. F. Kemp left immediately after commencement for Wyoming, and passed a week in the study of the Rambler Copper mine and vicinity under the direction of Dr. David T. Day of the U. S. Geological Survey. The occurrence of the platinum group of metals with the copper lends special interest to the mine. Subsequently, in company with professor Wilbur C. Knight of the University of Wyoming, trips were made to the titaniferous magnetite at Iron Mountain and into the Leucite hills. Professors Knight and Kemp plan a joint paper upon the latter, many new data having been accumulated regarding the structural geology of the Leucite hills.

The regular work of the second session in field geology for students in the Columbia School of Mines was conducted last year at Marquette, Michigan, by professor Grabau, owing to the illness of professor Kemp. This year it was given by professor Kemp at Bingham Canyon, Utah, during the week beginning July 13. A geologic map of the region around the principal mines was prepared by a class of fifteen, and observations were also made underground. In connection with this each pair of students will make a petrographical and chemical examination of the different rocks and ores found in the field. Every courtesy was extended to the party by the officials of the United States Mining Company, where headquarters were established, and by others in the camp.



No. 1. ONE SIDE OF METEORITE UNCOVERED.



No. 2. AFTER FURTHER EXCAVATION.

HENRY A. WARD.



No. 3. UNEQUAL WEATHERING OF MASS.



No. 5. METEORITE PARTIALLY UP-ENDED.

HENRY A. WARD.



NO. 4. VIEW TAKEN FROM ABOVE AND LENGTHWISE OF THE MASS.
SHOWS AT RIGHT HAND THE FISSURE.

HENRY A. WARD.



NO. 6. THE METEORITE FINALLY UP-ENDED.

HENRY A. WARD.

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No. 4.

ON BACUBIRITO OR THE GREAT METEORITE OF
SINALOA, MEXICO.

By HENRY A. WARD, Rochester, N. Y.

PLATES IV-IX.

For more than a century the meteorites of Mexico have attracted attention and record. In his great work on "La Nouvelle Espagne," published in 1811, Humboldt described in a broad and philosophical way the great field of the Toluca irons and the size of some isolated masses in the states of Zacatecas and Durango. From that day until this, naturalists and travellers in Mexico have examined and described this product of the country, commenting particularly upon their frequency and their size.

Their frequency has been greatly over-estimated. The total number credited to the Republic in Castillo's full catalogue, published in 1889, was 27. At the present day there are known 30 distinct localities, omitting the numerous points embraced in the distribution of the masses in two or three wide-spread showers. Comparison with other parts of the world shows that the relative number of Mexican meteorites is much less than seems to be generally supposed. Leaving out one or two extra-limital localities, the Mexican falls have all been in a belt some 1,000 miles in length, reaching from the 30th parallel of north latitude, south to the 17th parallel, and with an average breadth of about 280 miles. This belt of meteoric falls follows largely the central axis of the great Mexican plateau, reaching from the United States frontier-line southward through the Republic to near the Pacific. In this tapering truncated triangle which encloses about

280,000 square miles, there occur 28 well distinguished meteorite falls.

Turning to the United States we measure a like area, though of a somewhat different form, with its major axis east and west, and enclosing the six continuous states of Kansas, Missouri, Kentucky, Tennessee, North Carolina and South Carolina. This area covers 286,000 square miles and contains 64 meteorite localities, more than twice the number that we have seen in the Mexican belt. In India in an area of similar extension, which includes its northwestern provinces, we find 48 meteorite localities or nearly twice the number in the Mexican belt. It would seem then, that Mexico must vacate her claim often asserted, to preëminence in meteoric localities.

Only, perhaps, the wide-spreadness of some falls, notably in the states of Coahuila and Toluca may be distinctive, although this meets an approaching rivalry in the dispersion of some which we consider identical falls of aerolites in Kansas and in Iowa.

It would be interesting to notice here the fact of the high elevation of these three meteorite belts or areas above the general altitude of the country at large. This is especially remarkable in Mexico and in India. Also the fact that the Mexican meteorite list shows 23 irons to 7 stones; the United States as a whole 102 irons to 54 stones; while India gives 55 stones and only 2 irons. We cannot here digress to even guess at the possible cause of these phenomena.

The prominent character and preëminence of the Mexican meteorites is the vast size of many of them. In this matter of bulk they are unapproachable. Taking but ten of them, Chupaderos San Gregorio, Casas Grandes, Concepcion, Charcas, Descubridora, Bacubirito, Zacatecas and Apolonia, we find a total weight of 86.744 kilograms (191,076 lbs.) or 95½ tons. This equals an average weight of 9½ tons for each of these Mexican irons. If now we take the largest ten meteorites of the United States (they are in the order of their weight Red River, Tucson, Long Island, Canon Diablo, Mt. Joy, St. Genevieve, Sacramento Mts. Estherville, Brenham and Kenton Co.) we find their combined weight to be 8,470 lbs.; or 8½ hundred weight, as the average individual weight of the ten. In short, the Mexican masses weigh on an average

22½ times as much as our own. What may have caused this so vastly greater mass of Mexican meteorites we will not venture to define. Has the great height above sea-level of the Mexican plateau, with its drier air and drier soil, delayed the decomposition and wasting away of their irons? But Anighito in Greenland, Bendego in Brazil and Cranbourne in southern Australia, three giants, all lay close at sea-level, and all three were in exceptionally moist regions.

The Mexican government has taken an active and enlightened part in the protection of her meteorites. Twelve years ago it expended the sum of \$10,000 in bringing five of the largest to the capital, where they are mounted on huge iron pillars in the entrance court of the School of Mines.

Having during the last fifteen years paid visits to most of these Mexican meteorite localities, seeing most of the large masses before they had been removed from the spot where they fell, and where some of them had lain perhaps for many centuries, the writer acquired great interest in all that pertained to them. While in the capital a few months ago, studying and cutting some of the large pieces in the Museo Nacional, the writer sought almost in vain in scientific circles for substantiation and defining of stories which have long been current relating to an enormous iron meteorite existing in the state of Sinaloa, far in the north-west portion of the Republic.

The first and, so far as I can find, the only positive notice of this meteorite was in 1876. Then Senor Mariano Barcena, a noted Mexican scientist and astronomer, in a page article in the Proceedings of the Philadelphia Academy of Sciences devoted to Mexican meteorites, notices "an enormous meteoric mass lately discovered in the state of Sinaloa."

He says, "I can assure the Academy that its length was more than twelve feet." Many years later Castillo in his catalogue of Mexican meteorites refers to this same mass, giving its length at 3.65 metres; with 2 metres in height and 1.50 metres thick. Three years later, Eastman, of the United States Naval Observatory, taking the above measures as being correct, estimated its weight as 40,800 kilograms, or about 42 tons. Brezina, Cohen and Wulffing speak of it as weighing 50 tons, and as being the largest meteorite in the world. But

in all this there was no definite description of the mass, and no one who mentioned it claimed to have seen it. We were anxious to ascertain about all this. The Mexican savants were all interested in having this great celestial body investigated. One of them, Senor Jose C. Aguilera, the director of the Instituto Geologico, a government institution, and the present headquarters of the geological survey of the Republic, aided me in obtaining from the Minister of State letters to the governor of Sinaloa and to the director of mines in that state. I had decided to visit Bacubirito, for so the place and the meteorite itself was called, and see what was fact and what was rumor about it. So on the 2nd of April of the present year I started out to resolve the matter. Sinaloa is a hard state to reach from the city of Mexico. One must pass far around to the north through the United States, returning south through Sonora, a journey, of over 2,000 miles, or go by the Pacific coast, a shorter but harder route. We took this latter, crossing by train and mule-back to Manzanillo, the sea-port of the state of Colima, and thence by steam up the coast for six hundred miles to Altata, on the east coast of the gulf of California; thence 60 miles by cars to the city of Culiacan, the capital of Sinaloa. Here we met the governor of the state, and from him obtained letters to authorities further up the country. We also got an outfit of provisions, a carriage with four mules, and an American photographer who accompanied us with his camera. Bacubirito is 95 miles to the north and west of Culiacan. Our drive took three days, over a very rough road, crossing some streams and ravines, and gradually rising to and among the lower foot-hills of the Sierra Madre, the great Cordilleras chain which separates Sinaloa from the states of Chihuahua and Durango. Bacubirito itself, our goal in this search, is a small but very old mining town situated on the Rio Sinaloa in the latitude 26 and in west longitude 107. The elevation above sea level is some 2,000 feet. The meteorite is seven miles nearly due south from there, near the hamlet called Palmar de la Sepulveda. Here we found it on a farm called Ranchito, which fills the narrow mountain valley or interval between two spurs of the foothills, running nearly north and south. It lay in a corn field, close by the eastern edge of this vale where the level ground began

to rise against the hill-side. The valley and field were of black vegetable soil, several feet in thickness. In this soil the great meteorite lay imbedded; its surface but little below the general surface of the field around it, but with one end slightly projecting above the level. The other end was so deeply imbedded in the soil, and so apparently undisturbed or even uncovered, that it was easy to see why the size and measures of the mass had been uncertain. It was a long, monstrosous boulder of black iron which seemed to be still burrowing to hide itself from the upper world. Its surface form was something like that of a great ham. We could walk for many feet along and across its surface, surveying these dimensions as far as they were exposed, but knowing nothing of how far the mass penetrated the soil beneath. Our first work was excavation. For this there was no lack of help. We soon got no less than 28 stout, able-bodied, willing Peons, who were delighted to work for us at fair wages. We undertook an excavation of about 30 feet on a side, with the great meteorite lying within. In a single day we passed down through nearly 4 feet of the soft vegetable soil. At the end of that time the meteorite had assumed the appearance shown in photograph plate No. 4, its upper surface and one side being revealed. On this surface the characteristic "pittings" were well marked, covering the entire surface. They were very regular in size, about 2 to 3 inches across, with well defined walls, yet quite shallow. The general form of the mass seen from the side was that of one side or ramus of a huge jaw. The surface was very even, with no holes due to the destruction of troilite nodules. Nor were there any points which showed the devastation of deep rust. The dryness of the soil and the large portion of nickel in the meteorite's composition had doubtless impeded this. As often happens in such cases, the part which had been most above ground was best preserved with a light oxydized crust, brown and somewhat bronze-like in appearance. On one side there was a deep crack running horizontally through nearly half the length of the mass. At one end this crack was too narrow to insert a knife-blade. Going toward the other end it increased to a fissure wide enough to admit our hammer handle and finally our arm. This fissure at a distance of some three feet from the

smaller end of the mass cut off the lower part from the upper; the latter extending beyond in diminished size for three feet further. Our Mexicans were astonished at the revelation of their own work: they marvelled alike at the size of the mass as their digging had developed it, and at our credulity in believing that it had ever fallen from space above. View seen on plate iv No. 2 gives a somewhat oblique view after further excavation. Plate v Nos. 3 and 5 gives the same view, and shows the unequal weathering of the mass, the part most exposed being the least weathered. Plate vi is another view taken from above and lengthwise of the mass. This shows on the right hand the fissure in the mass.

By the end of the second day we had carried our excavation to an average depth of about 6 feet on every side. The black vegetable soil was from three to four feet thick. Below it was a porphyry rock, common in this part of the country, much broken up by natural cleavages and a good deal decomposed in situ. The vegetable soil passed very gradually into this rock, and seemed to have unquestionably formed above it, as an operation of gradual change. Immediately around the meteorite we had dug much lower, leaving the great iron mass poised on a pillar or pedestal of the undisturbed rock. Finally we performed a feat of moving the great mass. To lift one end would have been a physical impossibility, all our men with the stoutest tackle in the district could not have done that; but it needed little mechanical aid to make the mass move itself. We attacked with our long iron bars one side of the supporting pedestal on which it was balanced. It was slow work, for the rock seemed to be here somewhat less decomposed. After long chiseling away one side of the pedestal, the center of gravity was reached, and with a slow, almost dignified movement the great meteorite sank at one end, and assumed the semi-vertical position which is brought out in plate vii. The photographer is seen standing midway of the mass. Incidentally there is well shown the depth of our excavation below the level of the corn field. We upset the mass in an effort to ascertain, if possible, by the nature of the rock beneath it, the recent or the ancient fall of the mass. Was the soil already there when the meteorite fell, and did the latter by virtue of its weight crush through it to the rock? In the

atter case it seems probable that some of the soil should have been caught and held between the meteorite and its bed. A good deal to our surprise we found that this bed was a clean depression crushed into the rock with absolutely no trace of soil between it and the part where the full weight of the mass had fallen and lain. It would thus *seem* that the meteorite had fallen on the bare surface of this district at a period before the vegetable soil had begun to form here. This would be an interesting and astounding fact, carrying back the fall of our meteor to a remotely distant period, perhaps thousands of years. But there are other conditions which would need careful consideration before accepting such a momentous conclusion.

The wonderful preservation of the mass, with its little oxydation and the clean, sharp-rimmed pittings which cover its surface, seem to point to a more modern sojourn within the destroying influences of our air and moisture. We leave this for future consideration.

It is an interesting fact that this, the largest and probably the heaviest meteorite mass yet discovered on our globe, should have fallen so near the present border of our own country. Interesting, too, that Mexico with all its other extra large meteorites should have received this champion mass.

The extreme measures of Bacubirito, for so our meteorite from the first has been called, are:—

Length, 13 feet and 1 inch.

Width, 6 feet and 2 inches.

Thickness, 5 feet and 4 inches.

Its form, as shown by the photographs, is extremely irregular, and though measures have been taken around the mass at many different points, its cubic contents cannot be calculated with more than an approximation to accuracy.

The five largest meteorites known to science today are:—

Bemdego (Brazil) 5 1-3 tons.

San Gregorio (Mexico) 11 1-2 tons.

Chupaderos (Mexico) 15 2-3 tons.

Anighito (Greenland) 50 tons.

Bacubirito (Mexico) 50 tons.

The first three are weights proven on scales. The last two are thus far simple estimates. How far estimated

weights based on simple guessing may differ from proven weights is well illustrated by the case of Chupaderos, one of the meteorites just cited. Fletcher, the noted mineralogist of the British Museum, says of it, "According to one recent estimate its weight is 15 tons, according to another it is 82 tons." Anighito, the great Greenland meteorite, has been guessed at all figures from 30 to 100 tons. A late unofficial estimate of it, after careful measuring, puts its weight at 46 1-3 tons.

Should the Mexican government, as we some expect, move the great mass, as it has done all the others, to the capital, its exact weight will be finally and definitely known.

Whichever mass shall, after accurate calculation, prove to be the heavier, it will ever remain of interest that the two largest meteorites known to our earth shall have fallen on the North American continent, one far toward its northern end, the other toward its southern.

The inner structure of this meteorite is interesting as showing the octahedral system of crystallization in a very marked degree. We know of no other meteoric iron which shows this equally, unless it be that of the Sevier Co., Tennessee, or San Angelo, Texas. Fractional surfaces show crystallization plates with faces from 3 to 19 mm. in greatest diameter. Many of these faces are covered with fine films of taenite, which in most cases are of the characteristic bronze yellow color. Acid brings out the Widmanstätten figures in a beautiful manner. From the coarse crystals on a fractured or a weathered face of this iron, we might anticipate that etching would reveal a large, wide pattern in its markings. As a fact quite the converse is true. The figures, while very sharp and clear are small in pattern and are composed of narrow blades of kamacite which are but a fraction of a millimetre in diameter. At intervals, these blades appear to be of more than double that thickness; but when examined with a glass it is seen that these apparently broader plates are composed of what might be expressed as bundles of the narrow kamacite bands. The rhombic figures on the etched face will average from 1½ to 5 mm. in diameter, the two angles of the same being 60° and 120°, while the triangular markings will generally range from 8 to 15 mm. with

angles of 55°, 65° and 70°. Troilites are particularly scarce, but two or three small ones having shown on any of the sections made. The iron is essentially tough, although not more dense than in the majority of siderites.

The specific gravity of Bacubirito is 7.69. Its analysis has been made by Prof. J. E. Whitfield of Philadelphia, as follows:

Iron.....	88.944
Nickel.....	6.979
Cobalt.....	0.211
Sulphur.....	0.005
Phosphorus.....	0.154
Silicon.....	Trace.

We succeeded after a long protracted effort in detaching from the mass an already partly-loosened piece of about 11 lbs. weight. This, polished and etched on one side, showing the beautiful Widmanstätten figures, has taken its place in the Ward-Coonley collection of meteorites now on display (on deposit) in the American Museum of Natural History in New York.

**LISTS OF FOSSILS FROM THE LOWER HALF OF
THE CONEMAUGH FORMATION NEAR MOR-
GANTOWN, W. VA., COLLECTED IN 1870
BY DR. JOHN J. STEVENSON, AND
IDENTIFIED BY F. B. MEEK.**

I. C. WHITE, Morgantown, W. Va.

During the recent excursion led by the writer through the coal Measures of western Pennsylvania and West Virginia, frequent inquiries for lists of fossils were made by members of the party.

The only authentic and reliable identifications that have been made from the regions referred to were published by Dr. John J. Stevenson in the 3rd Annual Report of the Board of Regents of the West Virginia University for the year 1870. As this publication is very rare and few geologists have access to it I have been requested to have the names of the species republished. This has been done in the following lists and I have also appended a portion of the letter of Mr. Meek pertinent

thereto written to Dr. Stevenson under date of Nov. 8th, 1870. The only commentary upon this letter which seems necessary is that the beds in question do not come so low in the Coal Measures as Mr. Meek supposed, so that instead of coming 1000 to 1500 feet below the Nebraska horizon holding the same fossils, they probably come at about the same geological level, since marine conditions terminated entirely in the Appalachian province with the deposition of the Crinoidal (Ames.) limestone and its accompanying shales. The fauna thereafter was of fresh or brackish water type, and at a few hundred feet (650) higher, typical Permian plants make their appearance in the roof shales of the Waynesburg coal. I have arranged the fossils into two lists instead of the one as given by Mr. Meek, otherwise the following is an exact copy from the publication in question, pp. 67-71.

"The specimens sent from the lower Coal Measures are nearly all forms common in the coal series of Indiana, Illinois, Missouri, Kansas, Nebraska, etc., though few of them have before been found so far eastward. In some of the states mentioned, nearly all of these species range through the whole of the Coal Measures. Some of them, however, are locally more restricted. This great range of the species of invertebrate remains in the Coal Measures of the western states has long since satisfied me that these fossils cannot generally be relied upon as a means of identifying particular beds or horizons in our Coal Measures throughout wide areas; though particular groupings of species may sometimes serve as guides in this respect, within limited areas. The Coal Measure forms, however, enable us at once to distinguish beds of that age from any of the lower Carboniferous or older rocks.

The great length of time through which most of these fossils must have continued to live, will be better understood when it is stated that nearly *all* of the species enumerated in this list from the lower Coal Measures of West Virginia, also occur even in the upper Coal Measure beds in Nebraska, referred by professors Marcou and Geinitz to the *Permian* or so called *Dyas*. Indeed the collections from these two widely separated localities and horizons, contain so many of the same species, that if shown to almost any geologist unacquainted with the range of species in our Coal Measures, he would scarcely hesitate to adopt the conclusion that they came from *exactly* the same horizon in the series. Yet from what is known of the geology of your region, and that of the states farther west, it is probable that the beds from which your collections were obtained, hold a position from 1,000 to 1,500 feet or more below those alluded to in Nebraska.

From such facts as this, it would seem that although there were many elevations and depressions, as well as other consequent changes,

natic and other physical conditions affecting animal life, must
mained remarkably uniform throughout the whole of the long-
ed coal-period.

Very truly yours,
F. B. MEEK."

of Fossils identified by F. B. Meek from horizon of Crinoidal
s Limestone, near Morgantown, West Virginia.

noidal fragments—Some pentagonal, star-shaped discs of col-

oidal columns.

ipronites crassus Meek and Hayden.

netes smithii Norwood and Pratten.

ss. Seems to differ from *C. granulifera* Owen, only in being

oductus nebrascensis Owen.

oductus prattenanus Norwood.

oductus semireticulatus Martin sp. Seems to be rare in, our

cina nitida? (?)

udomonotis. (Monotis of some authors but not of Brown.) A
it, but showing exactly the irregular radiating costæ and striæ,
ulted scales seen on the ribs in that genus.

iculopecten carbonarius Stevenson, sp.— Pecten broadheadi
e, and Pecten hawni Geinitz.

alina subquadrata Shumard, var. *ampla*.

lina. Undetermined species. Very small. Probably a young

risma. Undetermined species.

cula ventricosa Hall.

cula parva McChesney.

ula anodontoidea Meek.

culana bellistriata Stevenson, sp. A very small attenuated vari-
ommon in the so-called upper Dyas, Nebraska City, Nebraska.

rtella. Undetermined species.

rodon obsoletus Meek.

rocheilus primigenius Conrad.

rocheilus ventricosus Hall.

rocheilus. Undetermined species.

v species.

lerophon montfortianus Norwood and Pratten.

lerophon percarinatus Conrad.

lerophon carbonarius Cor.

rophon meekianus Swallow.

rotomaria grayvillensis Norwood and Pratten.

rotomaria. Undetermined species. A very small depressed

hoceras cribrosum Geinitz.

cies known to range through the whole of the Coal Measures in the
ren into the upper beds at Nebraska City, Neb., referred by Profs.
and Geinitz to the Permian or so-called Dyas.

**Nautilus occidentalis Swallow.*

Nautilus. Undetermined species.

Productus. Undetermined species. Very small, concentrically wrinkled.

**Athyris subtilita Hall.* Very abundant and presenting all the usual varieties.

**Spirifer (Martinia) planoconvexus Shumard.*

**Spirifer cameratus Morton.*

Aviculopecten. Undetermined species. Probably *A. occidentalis Shumard.*

List of Fossils in Roof Shales of Upper Freeport Coal, Near Morgantown, Monongalia County, West Virginia.

**Crinoidal columns.*

Erisocrinus. Undetermined species.

**Aviculopecten carbonarius Stevenson sp.*—*Pecten broadheadi Swallow*, and *Pecten hawni Geinitz.*

Allorisma. Undetermined species.

**Nucula ventricosa Hall.*

†*Nucula anodontoides Meek.*

**Nuculana bellistriata Stevenson sp.*—A very small attenuated variety. Common in so-called upper Dyas, Nebraska City, Nebraska.

†*Yoldia carbonaria Meek.*

†*Yoldia stevensoni Meek.*

**Schizodus.* Undetermined species.

**Edmondia aspenwalensis Meek.*

Astartella. Undetermined species.

Macrocheilus primigenius Conrad.

**Macrocheilus ventricosus Hall.*

Macrocheilus. Undetermined species.

Polyphemopsis peracutus Meek and Worthen.

**Euomphalus rugosus Hall.*

**Bellerophon montfortianus Norwood and Pratten.*

**Bellerophon percarinatus Conrad.*

**Bellerophon carbonarius Cox.*

Bellerophon meekiana Swallow.

**Pleurotomaria grayvillensis Norwood and Pratten.*

**Orthoceras cribrosum Geinitz.*

**Nautilus occidentalis Swallow.*

**Phillipsia sangamonensis Meek and Worthen.*

**Productus nebrascensis Owen.*

**Productus prattenanus Norwood.*

**Athyris subtilita Hall.* Very abundant and presenting all the usual varieties.

Productus. Species undetermined. Very small, concentrically wrinkled.

**Spirifer (Martinia) planoconvexus Shumard.*

**Spirifer comeratus Morton.*

Aviculopecten. Undetermined species. Probably *A. occidentalis Shumard.*

**Hemipronites crassus Meek and Hayden.*

A BRIEF SUMMARY OF GLACIER WORK.

A. C. SCOTT, Kingston, R. I.

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INTRODUCTORY NOTE.

The summary of glacier work presented in the following pages which was written as a seminary paper in a course in geology at the University of Wisconsin, does not presume in the least to be a complete resumé of the subject.

In attempting to arrange an outline of the work it was apparent that the literature nowhere included a summary, and so it appeared on completion of the paper that the few facts therein collected might be more or less useful to others interested in glaciology. Indeed this may seem sufficient apology for publishing an article that does not treat the subject exhaustively.

Present day knowledge concerning the subject of glaciation has developed almost wholly within the past century.

One of the earliest important statements concerning glaciers was made by James Hutton, the father of modern geology, in his "Theory of the Earth, with Proofs and Illustrations," which was given to the world in 1795. This work was evidently intended by its author to consist of four parts, though prior to his death in 1797 only two parts had been

fully completed and published, and it is in the second part that he refers to the transport of erratics by ice*. The manuscript of a portion of the third part, for over forty years in the possession of the Geological Society of London, has recently been published (1899) by the council of the society, with Sir Archibald Geikie as editor.

Geologists of the present day, however, learn also of Hutton's views through his friend and biographer, John Playfair, in the "Illustrations of the Huttonian Theory of the Earth," published in 1802. Playfair therein voices the opinion of Hutton concerning glaciers when he says that "for the removing of large masses of rock, the most powerful engines without doubt which nature employs are the glaciers, those lakes or rivers of ice which are formed in the highest valleys of the Alps, and other mountains of the first order. Before the valleys were cut out in the form they now are, and when the mountains were still more elevated, huge fragments of rock may have been carried to great distances; and it is not wonderful if these same masses, greatly diminished in size, and reduced to gravel or sand, have reached the shores or even the bottom of the ocean."

This original suggestion concerning the transportation of the erratic blocks of Switzerland by glaciers, at a time of great extension of ice in the Alps, apparently passed out of mind, however, till some thirty years later. Venetz and Charpentier were first to resume this study of glacial work in tracing the dispersal of crystalline rocks of the central Alps over the great Swiss plain to the Jura mountains; † but it remained for another to comprehend the full significance of the conditions observed, and to evolve investigations which led to the recognition of the Ice age, with its supremely important bearing upon geology, and the antiquity of man.

Jean Louis Rudolph Agassiz is the man who is universally recognized as the founder of glaciology. Agassiz was born in Switzerland in 1807, rose to distinction by his scientific work in Europe previous to 1846, when he came to the United States. Two years later he was elected professor of zoology and geology at Harvard University, and made

*Theory of the Earth, Part 2, pp. 174, 218.

†Schweizer Gesell. Verhandl. 1834, p. 23.

Ann. des Mines VIII, 1835, p. 213.

Leonhard and Bronn, Neues Jahrb., 1837, p. 472.

this country his home till his death in 1873. Two of his most important contributions to glaciology are "*Etudes sur les glaciers*" (1840) and "*Système Glaciaire*" (1847). It is interesting to note in connection with the work of Agassiz in Europe that he believed "the great extension of ice was connected with the last great geological changes on the surface of the globe, and with the extinction of the large pachyderms, whose remains are so abundant in Siberia. He believed that "the glaciers did not advance from the Alps into the plains, but rather that the ice once covered all the grounds, and finally retreated into the mountains."* He further demonstrated the identity of the conditions which obtained in Britain with those of Switzerland, claiming that "not only glaciers once existed in the British Islands, but that large sheets of ice covered all the surface," † and in extending his investigations to America, showed that the northern part of this continent also, including the northern and eastern portions of the United States have been under an enormous ice mass.

In the history of glaciology his researches have been most admirably supplemented by the works of Buckland, Lyell, Darwin, Archibald Geikie, James Geikie, Dana, Le Conte, Daubrée, Heim, Forbes, and many others who might be mentioned, until the literature upon the subject is not only most voluminous, but highly instructive concerning the past history of the world as indicated by present day glaciological evidence.

In a comprehensive work on glaciers published twenty years ago, Prof. Shaler, of Harvard University, expressed the opinion that "Of all the elements of our understanding of the past, the knowledge of the changes of condition in the earth brought about by glaciers is clearly the most important."‡ Whether this statement still remains undisputed, is perhaps open to question, yet the fact certainly holds that geology has a valuable corner stone that has been properly placed by glaciology.

The reference to the history of the subject here given is extremely brief, and interested students may read with

*The Founders of Geology, Geikie, A. p. 274.

†Proc. Geol. Soc., Vol. III. (1840), p. 331.

‡Glaciers. Shaler and Davis. 1881.

pleasure and profit, "The Founders of Geology," by Archibald Geikie, (1897), "Illustrations of the Huttonian Theory of the Earth," by Playfair (1802), and "Theory of the Earth," by James Hutton (1795).

Classification.

For convenience in considering this subject it may be divided into two general classes: glaciers of the present, and glaciers of the past. The former class may be said to include the existing glaciers of the mountainous portion of the globe, together with the polar ice sheets, while the latter class considers particularly the great continental glaciers.

We may further distinguish broadly between the two prominent types of present glaciers, which have been termed the Alpine or mountain glaciers, and the polar ice-fields of the Greenland type.* First, the area of the polar glaciers is enormous, compared with that of the Alpine; secondly, the maximum rate of motion is much greater in polar than in Alpine glaciers; and thirdly, the economic results produced by the one are vastly different from those produced by the other.

A glacier in general may be defined as a gigantic mass of ice formed from snow falling in altitudes above the snow line, and subsequently assuming a granular form, which, as it moves by gravitation to lower levels, becomes compacted into a mass known as névé, which gradually takes on a characteristic blue, crystalline structure as the air is squeezed out by motion, and compression, and becomes glacier ice.

The Great Aletsch and Görner glaciers of the Swiss Alps, are typical examples of mountain glaciers, where, as is often the case, the main ice stream is produced by the combination of many tributary streams. The St. Elias Alps in North America, however, furnish the grandest examples of this type (which is known as Alpine because it was first systematically studied in the Swiss Alps) from the fact that Mt. St. Elias and Mt. Logan, its giant neighbor (19,500

*NOTE.—Some authors include in their classification, glaciers of the Scandinavian type, as separate from those here given. Such a classification may be preferable in some respects; the reason for not distinctively including it here is, that a glacier of the Scandinavian type is defined, according to Johnson's Encyclopedia, as "A broad sheet of ice accumulating on a mountainous plateau," et cetera. Therefore this type appears to find a place under "glaciers of the mountainous portions of the globe," as already stated.

feet high) are said to rise from the most thoroughly glacier covered region on the mainland of the continent. Hundreds of glaciers gather in the vicinity; the largest one of which is the Seward, the principal tributary of the Malaspina.

It may further be said that North America has existing glaciers of all the known types, excepting possibly the peculiar Scandinavian variety. Examples of the Alpine type have been cited; the Piedmont type has several representatives in Alaska, one of which is the Malaspina glacier. Greenland furnishes perhaps the solitary example of a continental ice sheet that can be investigated; and the so-called "tide-water" glaciers are numerous both in Alaska and Greenland.

Comparative size.

Peary's estimate is undisputed that about 600,000 square miles of Greenland is under a glacier of the continental type. Many of the tongues of this glacier extending into the sea through the ice fjords are of immense proportions, being hundreds of miles long in some cases, and several miles broad.

The Antarctic region has as yet been comparatively little explored. In a summary on the region, Dr. J. D. Murray considers that the southern pole is surrounded by a continent of about 4,000,000 square miles, being larger than Australia.* The land rises abruptly from the sea, having hills ranging from 3,000 to 7,000 feet in height with some peaks that are considerably higher. These are said to be covered with ice more uniformly and to a greater depth than in the Arctic region, and even at the coast, bare low lands or rocky cliffs are uncommon. The ice sheet descends from the slopes into the sea, and from it the great tabular bergs are formed, and also the immense ice cliffs which preclude satisfactory explorations into the interior. The ice is supposed to be from 1200 to 2000 feet thick. This estimate is made chiefly from the bergs that extend from 150 to 200 feet above the water, considering that ice floats with approximately nine tenths of its volume submerged. The sea is so covered with floating ice in that region that navigation is practically impossible beyond a latitude of 65 degrees.

*Geog. Jour. 1894, Vol. 1.

Thus it is that exploration in cold climates has, for obvious reasons, thus far been centered in the north. Lieut. Peary, as an indefatigable explorer, has of late enlarged our knowledge of Arctic geography.* He has shown that Greenland is an island and, further, has fixed the limits of this enormous territory. We are led to believe, however, that the Antarctic region may soon give up its secrets, for some of the best equipped, most costly, and most scientific expeditions ever planned have moved toward the southern pole. The two largest are those of Britain and Germany, each supported by government grants to the extent of \$250,000, with additional private contributions amounting to \$100,000. Two smaller expeditions are also sent out; one by the Scotch, and the other under the command of Dr. Otto Nordenskjöld, a nephew of the late Baron Nordenskjöld, the famous Arctic explorer.† These expeditions are equipped for a work of from three to six years, and if successful, our knowledge of the southern ice sheet will in the future, be based upon facts rather than hypotheses.

The single Alpine glaciers in comparison with the polar, are small; usually less than 25 miles long, less than three miles broad and vary from 200 to 300 feet in depth. It is said that the G6rner glacier has an area as large as three cities the size of London, or about 350 square miles; the Great Aletsch glacier, in 1880 was somewhat over ten miles long, being the longest of the Alpine glaciers in Europe, though covering an area of less than 18 square miles. The glaciers of the highest peaks of the Himalayas, one of which was climbed by Conway to a height of 23,000 feet, reach an extreme length of forty miles so far as known, and in some cases the ice is presumed to be about 1000 feet thick. The glaciers of the St. Elias Alps, previously mentioned, are of size corresponding in general to those of the Himalayas, as the Seward, for example, whose length is fifty miles and breadth three miles at its narrowest part;‡ other mountain glaciers of North America are quite comparable to those of the Alps, as for in-

*See "Northward over the 'Great Ice': a Narrative of Life and Work along the Shores and upon the Interior Ice Cap of Northern Greenland in the years 1886 and 1891-97. Robert E. Peary, 2 Vols. Illustrated. Frederick A. Stokes Co., New York, 1896.

†Review of Reviews, July, 1901. New Phases of Polar Research, Cyrus C. Adams.

‡Geog. Jour. 1898. Russel.

stance, the five glaciers of Mt. Shasta; the largest of these called Whitney glacier, after professor J. D. Whitney, of Harvard University, has a length of about two miles, and a width of from 1000 to 2000 feet.

As might be expected the glaciers found in the latitude of the equator are much smaller. Numerous glaciers are known to exist, however, in the Andes of Ecuador. They attain their greatest size upon the mountains of Antisana, Cayambe and Chimborazo, the latter having eleven distinct ones.

Velocity of Flow.

A consideration of the second point embraces the well known fact that glaciers are nearly always in motion, though under certain conditions the rate is very slow. Observations made upon glaciers in the Alps seem to show the average of the measured rates of flow is from one to three feet per day depending upon the size of the glacier, the larger moving faster. One of the early notes in this connection is made by Henry Thomas La Beche.* A ladder left by the geologist Horace Benedict de Saussure at Col. du Geant, in 1787, was discovered in the Mer de Glace, the continuation of the same glacier, having advanced about nine miles during the intervening forty-five years, or an average of nearly three feet per day. Observations made upon American Alpine glaciers show about the same rate of movement.

The motion of the Greenland ice sheet is said to resemble an inundation, as there appears to be a general movement of the whole mass of ice from the central regions toward the sea. Its force is concentrated largely at a few points, and to an extraordinary degree. These points are the fjords through which the annual surplus ice is carried away and discharged into the sea as icebergs.

Danish explorers measured the velocity of seventeen glacier tongues in the ice fjords of Greenland, repeating such measurements in both cold and warm seasons, and thereby showed that the movement was not influenced by seasons. Further, glaciers which produced bergs showed a movement averaging from thirty to fifty feet per day throughout the year. The great glacier of the ice fjord of Jacobshaven

*Manual of Geology, 1832.

having a breadth of nearly three miles was rated at fifty feet per day, and that of Karajak, four miles broad, at twenty-two to thirty-eight feet in twenty-four hours. * These figures show the average rate of motion to be at least ten times that of glaciers of the Alpine type.

"It has been stated as an empirical rule," says Prof. Harry Fielding Reid, † "that the velocity of glaciers in beds of uniform slope is greatest in the neighborhood of the *nèvé*-line, and diminishes as we leave it going up or down the glaciers." He proceeds immediately to show, however, that this rule has very important exceptions. Prof. Heim ‡ believes that the increased velocity of some Greenland glaciers near their ends, accords with the rule by considering the ends as the upper part of the glacier. Prof. Reid thinks this a mistake as the ends are some distance below the *nèvé*-line, but that the real cause is due to a lack of support in front, which Prof. Heim also mentions. It is considered probable that the under part of these tidewater glaciers does not move as fast as the upper, otherwise the bergs would be of comparatively thin sheets instead of immense irregular masses of ice.

There is a general law, however, that the flow is less below, than in the *nèvé*-line; this flow being equal it is stated, to the product of the average velocity, by the sectional area, by the effective density. The more rapid surface velocity often found, being thought by some authors to be due to the formation of immense crevasses which reduce the effective density. Where the glacier bed is of uniform slope the velocity and flow are said to increase together, though not necessarily in proportion.

Glacier Motion.—General Theories.

Glacier motion, ever since work on glaciers began, has been a subject of much interest, of careful investigation, and of keen controversy. It has engaged the attention alike of both geologists and physicists. De Saussure, as one of the first to consider the question, presumed that the weight of the ice

*Prestwich, *Geology*, Vol 2, Chapter 33.

†*Journal of Geology*, Vol. 4, 1896, p. 913.

‡*Handbuch der Gletscherkunde*, 1885, p. 160.

might be sufficient to urge it down the slope of the valley if the sliding motion were aided by water flowing at the bottom. *

Agassiz was the first to commence a series of exact measurements on glacier motion, in 1841, and to substitute, following Charpentier the idea of dilatation, for the "gravitation theory" of de Saussure. His theory was based on the idea that solid ice is always permeable to water, and contains innumerable capillary tubes. These tubes were supposed to imbibe water during the day, subsequently freezing at night, and expanding in such a way as to distend the whole ice mass. The immense force exerted by this distention was presumed to be sufficient to propel the glacier "down the valley."

Later on, however, the theory of Agassiz was replaced by that of Forbes, or the viscosity theory. This theory supposes motion among the *ultimate* particles *without rupture* and is regarded as the first to explain, in a partially satisfactory way at least, the differential motion of a glacier. Faraday showed in 1850, that if two pieces of ice having throughout a temperature of 32° F. and each melting at its surface, be made to touch each other, they will freeze together at the point of contact, the process being known as regelation. Upon this demonstration as a foundation Prof. Tyndal subsequently brought forward his regelation theory of the motion of glaciers, which, in brief, supposes motion among discrete particles, *by rupture, change of position, and regelation*. † Croll's Theory ‡ seems to be a modification of Forbes', in attempting "a physical explanation of the viscosity of ice." Another theory that deserves mention is that of Thomson. It is based on the fact that the fusing point of ice is *lowered*, and the ice promptly melted by pressure. Compared with Tyndal's theory the result obtains that differential motion in the one case is by fracture, change of position, and regelation; in the other by melting, change of position, and regelation. Many other theories have been advanced from time to time, but only those of apparently most importance, have been considered.

*"Voyages dans les Alpes."

† Le Conte, Elements of Geology.

‡ Croll, Climate and Time.

In reference to the Thomson * theory of liquefaction by pressure, it does not seem to the writer of this paper that such influence can enter into glacier movement in other than a very elementary way. It is proved in thermodynamics that where ice and water are together at the same temperature, if V_1 = the volume of unit mass of the mixture in the higher state, and V_0 = the volume of unit mass of the mixture in the lower state, then $L = t(V_1 - V_0) \frac{dp}{dt}$, where (t) is the absolute temperature, or $274 + 0^\circ\text{C.}$, and L = latent heat of unit mass in foot pounds. If we take L as latent heat of one pound of the material, and V_1 and V_0 as volumes in cubic feet of one pound of the material, then the formula holds for (p) reckoned in pounds per square foot. Now in ice water $V_0 = .01747$

$V_1 = .01602$ when (t) = $274 + 0^\circ\text{C.}$, and (p) = 14.7 pounds per square inch, or 2116 pounds per square foot.

Hence $\frac{dp}{dt} = -278100$, a constant; the quantitative meaning of the expression $\frac{dp}{dt}$ is, obviously, that the melting point lowers at the rate of .001 of a degree for an increase pressure of 278 pounds per square foot.

If we consider a given glacier to be 1000 feet thick then the pressure upon one square foot at the base would be $1000 \times 62.5 \times .918 = 57000$ pounds (Approx.). At the rate then of .001 of a degree for every 278 pounds we have for the total 57000 pounds a lowering of the melting point by only a little over two-tenths of a degree. It is true, however, that this decrease would aid slightly in producing liquefaction at the under surface of the glacier.

It is generally conceded that glacier ice acts like a viscous substance, and that its motion is fundamentally due to the weight of the ice itself. It seems that there are no available experiments bearing upon the sliding of ice over its bed other than those of Hopkins. † He used a number of pieces of ice on a rough sandstone slab, and found that the movement down the slope was uniform and approximately proportional to the pressure, and to the angle of inclination, for angles

*Proc. Roy. Soc. 1856-7.

†Phil. Mag. 1845, Vol. XXVI. pp. 3-6.

between 1° and 10° . With the sandstone polished the movement was observed at an angle of forty minutes. The laws of friction between solids are found to be inapplicable to the conditions of a glacier on its bed, though the angle of slope of the bed obviously is an important factor in glacier motion, and particularly so in the matter of erosion, which will be considered later.

The Rev. Coutts Trotter has described experiments * showing that glacier ice will shear under small forces if allowed sufficient time, and more recent experiments by Mügge † appear to prove that the apparent viscosity of glaciers is partly the result of shearing along the cleavage planes of the crystalline granules of the glacier ice.

A study of some of the larger Swiss glaciers, by Deeley and Fletcher ‡ concerning glacier structure, and its bearing upon glacier motion, is interesting because it involves methods somewhat different from those of their predecessors. A polariscope was used and sketches made purporting to show the character of the crystalline particles in a satisfactory way, just as they found them in the glaciers. Glacier ice had, of course, previously been regarded as a crystalline aggregate, by Heim, McConnell, Bertin, Grad, and others, the individual crystals fitting closely without the presence of a matrix. This conception is verified by Deeley and Fletcher, who further show that the optical structure of each grain is uniform, as indicated by the polariscope, but the bounding surfaces are very irregular and usually curved. The optic axes of neighboring grains appear to be arranged at random, and the surfaces of the majority of the granules are seamed with exceedingly small furrows. The relation between these furrows or striae and the optic axis, however, is not noted. It is believed that the striae are analogous to those seen on other crystals, and are due to the alternation of two faces of crystallization. A sketch of such striated crystals from the ice-cave of the Rhone glacier, § shows no definite direction of the striae with reference to the crystal mass, or to the neighboring crystals.

*Proc. Roy. Soc. 1885, Vol XXXVIII, pp. 92-108.

†Jour. of Geol. 1895.

‡"Structure of Glacier Ice and its bearing upon Glacier Motion."

Geol. Mag. 1895, pp. 152-162.

§Geol. Mag. (1895), Plate 156.

In this connection we may note one point more concerning individual crystals. McConnell and Kid have indicated * that a *single crystal* of ice will not change its shape under either tension or pressure applied at right angles to the optic axis, and therefore is non-plastic. Their experiments have proved conclusively, however, that glacier ice *as a whole is plastic*, at a certain temperature at least, both for tensile and compressive stress.

From such facts the conclusion is drawn that the observed viscosity must be due to an action at the interfaces of the crystals, such that their shape is altered in a way to allow them to change their relative positions. A hypothesis of this character is elaborated by Deeley and Fletcher who arrive at the conclusion that glacier grains may change their sizes and shapes under comparatively small stresses, and further that they may readily *shear*, or slide over each other without actual fractures occurring.

A later contribution by Hobson † confirms the crystalline structure ideas of Deeley and Fletcher just considered. He saw at Chamounix in September, 1896, without the aid a polariscope, similar phenomena to that already noted of the crystals in the ice-cave of the Rhone glacier. "The ice" he says, "was disintegrating into separate pieces of irregular form, each an inch or thereabouts in diameter, and fitting exactly together, with inter-locking projections and cavities, so that the structure reminded one of a toy dissected map." He also suggests that it might be possible to show the same thing by immersing glacier ice in hot water. An excellent paper on the movement, melting and interior temperature, of the Hintereis glacier, of the eastern Alps, was published in 1899, by Drs. Blumcke and Hess ‡.

Movement in Zones of Fracture and Plasticity.

While it may be unwise to presume to add materially to the vast amount that has been written on the cause of glacier motion, it may not be entirely out of place here to make some suggestions that have come to the writer in connection with a study of glaciers.

*"On the Plasticity of an Ice-crystal," McConnell. Proc. Roy. Soc. Vol. 49, p. 323, 1891.

†Geol. Mag. 1896, p. 572.

‡Untersuchungen am Hintereisferner Wissensch. Ergans L. Leit des Du. O. Alpenvereins 1 Bd. 2 Heft.

Since it is reasonable to presume that motion is by no means confined to the upper or surface layers of a glacier, but has to do with the whole thickness, it is here proposed to consider the mass as divided primarily into two parts.

1. An upper zone of fracture, or crevasses.
2. A lower zone of constant plasticity. *

The portion of a glacier above which the ice is under less weight than its yielding resistance is in the zone of fracture or crevasses.

The first point to be considered in connection with this zone rests upon some interesting experiments upon ice blocks by Col. William Ludlow (1880-81) †, A. Fruhling (1885) ‡, C. W. Beach, A. M. Mann, and H. E. Reeves (1895) §.

The results of these experiments as far as recorded show that the maximum yielding resistance of pure ice a few degrees below the freezing point, to compressive stress, is under 300 pounds per square inch. It thus appears that crevasses or cracks of any sort cannot exist below a limited depth. To determine this depth, it simply remains to calculate the height of a column of ice one square inch in cross section which shall have a weight of three hundred pounds and the result shows this to be not over 750 feet. It should be said here that all these experiments show a wide range of results, largely due, doubtless, to variable quality of ice and temperature and rate of deformation; so that an *average* rather than a maximum value, as above cited, would reduce the depth limit to about one-half the value given, or 300 feet, approximately. Another point to be considered, is the question as to whether the ice blocks tested were of the proper dimensions to give the correct results for larger masses of this material. The specimens used by all of the experimenters, so far as is apparent to the writer, were *cubes* of various sizes.

*This idea, and others also, embodied in this paper, have originated primarily from a study of "Principles of N. A. Pre-Cambrian Geology," and "Metamorphism and Rock Flowage," by Prof. C. R. Van Hise, Rep. U. S. Geol. Survey, 1894-95; Bull. Geol. Soc. of America, Vol. 9, pp. 269-328.

†"Observations on the Crushing Strength of Ice." Proceedings of the Engineers' Club of Phil. 1884, Vol. IV, p. 93.

‡Zeitschrift des Vereines deutschen Ingenieure. May 9, 1885, p. 357.

§Digest of Physical Tests, 1896-97.

It has been shown by Prof. Johnson * that brittle materials fail under a compressive load, by shearing on definite angles, and that the resistance to move along these angles is composed of two parts. "First, the strength of the material to resist shearing, and second, the frictional resistance to motion along the plane." Moreover, he says, "The relation of crushing strength to relative dimensions of specimens is a very important matter. Hitherto nearly all crushing test specimens of brittle materials have a cubical form. So long as the theoretical angle of rupture was thought to be 45° , this was proper, but since this theoretical angle approaches 60° , it is evident that the height of the specimen should be at least one and one-half times the least lateral dimension, in order to allow of failure on a normal angle."

Professor Johnson gives a mathematical demonstration of this important conclusion, which is also verified by the results of experimental tests. It is shown in the case of some limestone blocks which were tested, that when the cubical form was used, the results were 9 per cent greater than would have been true if the specimens had been chosen of the proper height. He says, "The unit strength of the material is no function of the size of the specimens, but only a function of its form," and that "Crushing test specimens should be true prisms in form." The work of professor Johnson did not include experiments with ice specimens, yet it is noticeable that the characteristic appearance of the ruptured materials, as represented by half-tone cuts, appears to coincide with the described appearance of the ruptured ice blocks.

It is to be regretted that no photographic representations of the broken ice specimens are given by any of the experimenters. Since, however the more compact specimens of ice "broke suddenly with report," it is probable that the ice behaved strictly as a brittle substance at the lower temperatures. This being true, the apparent strength of the cubical blocks as tabulated may have been, on the whole, nearly one-tenth too high. This suggestion is made here, not so much to criticise the work referred to, upon the crushing strength of ice, as to indicate to future experimenters a possible elimination of error.

*"Brittle materials under compressive stress," J. B. Johnson. Digest of Physical Tests, 1896-97.

From what has been said, a reason is indicated as to why the crevasses never extend completely through the larger and deeper glaciers, although they may be immense openings at the surface.

Col. Ludlow says in regard to the series of 12 inch cubes which he tested, "It was found that when subjected to pressure from whatever direction, the ice almost invariably resolved itself into small vertical columns, which, when the pressure was continued, buckled slightly and compressed, until in several cases, under a further increase of pressure, the block exploded with a loud report; this, however, only in the case of the better and more compact specimens. By vertical columns is meant columns normal to the natural surface of the ice." * The results of Beach, Munn, and Reeves are very similar in this respect, † for they say: "Ice, when subjected to pressure, is resolved into columns whose direction is normal to the surface which was in contact with the water while freezing."

The same experimenters show, in a table, that when the temperature of the testing laboratory, as well as that of the ice-block tested, were well below 32°F., viz., 21.2°F. for the laboratory, and 12.2°F. for the ice block, the specimen always "*broke suddenly*" and usually with report, but when the temperature of the laboratory and test blocks were but a few degrees below 32°F., many of the specimens "*gave way gradually*."

These results indicate an inherent tendency in ice masses to rupture along planes normal to the natural surface of the ice, and also to exhibit brittleness under conditions where the temperature is well below 32° F. They further show that the breaking of ice at a low temperature is of the nature of a shock. Prof. Russell has observed in connection with glaciers, that the formation of cracks which later open as crevasses is attended by rumbling noises and sharp crashes, with vibrations of the ice-mass as though an earthquake wave acted upon it. ‡

Gravity, the dominant force in glacier motion, acting to urge forward the ice mass accomplishes the greatest movement

*Proceedings of Eng. Club of Philadelphia, cit.

†Digest of Physical Tests, cit.

‡Glaciers of North America. Professor I. C. Russell, 1897, p. 8.

in the central portions of the surface, since the friction between the mountain sides and the ice particles is greater than that between the ice particles themselves. This active mechanical stress results in a differential motion of the ice mass which is of the nature of both plane and torsional shear. The stress is great enough to overcome the strength of the solid and the ice yields by snapping asunder, thus forming a miniature crevasse. The mechanical stress may also be aided more or less in the formation of cracks, by the factor of contraction which tends to take place in the ice as the temperature decreases. The surface layers are especially susceptible to this influence, since the temperature of the air above the ice is likely to be at times far below the freezing point. Furthermore cracks once started would not be nearly filled at once with water from below, as is frequently the case with lake ice, * but would, so long as mechanical stress and contraction continue open wider and deeper, finally resulting in vast impassable chasms.

If the ice travels over a very uneven bed, as is often the case with Alpine glaciers, some portions become engulfed, while the upper parts slide over them, and here the formation of immense crevasses is greatly augmented. Evidence is plentiful to show, however, that the upper portion of nearly all glaciers is traversed by fissures or crevasses, regardless of angle of slope, or volume of the ice mass. These fissures beginning as very small cracks will increase in size until a more equable slope is reached, or a rise in temperature occurs, when there is at once a tendency for the crevasses to close, and the ice regains its former solid condition by regelation. Again and again are repeated the before mentioned processes of rupture by mechanical strain and contraction, with subsequent repair by pressure and regelation and thus the glacier ice in the zone of fracture moves onward down the slope.

The movement of ice in this zone would be expected to comply with observed conditions, viz.: a more rapid rate in summer than in winter, and a greater movement by day than by night. During the time when the temperature of the air in contact with the ice is falling, the resistance to the onward moving force of gravity is increased, and contraction of the

*"Ice Ramparts," E. R. Buckley and C. R. Van Hise. Trans. of the Wis. Academy of Sciences, Arts, and Letters, Vol. 13.

ice mass is also taking place, while during periods of rising temperature, the surface of the ice becomes more mobile, and the mass moves forward more easily under mechanical stress.

The limit to which crevasses extend, as already pointed out, doubtless depends chiefly upon the weight of the superincumbent ice, though it is also probable that different conditions of stress may exert some influence; and, further, microscopic fractures might exist where macroscopic ones are not discernible, and so under certain conditions throughout a limited thickness below the zone of fracture, what might be called an intermediate belt of combined fracture and plasticity exists.

Here under certain conditions of temperature, and acting pressures in the ice mass itself, the ice might either fracture, or move as a plastic substance. *Sudden* pressures, or the lowering of the temperature, or both, would produce fracture, when reverse conditions would cause the ice to behave like wax. It is probable that combined forces in this space may be largely responsible for the fact that the movement of any given point in a glacier may vary from day to day, or hour to hour, because folding and thrusting of the ice would naturally occur, which, in turn, would make its influence felt on the observed surface ice above. And, further, a valley having a particularly irregular contour, would have such an effect upon the movement of ice in this space, as to augment the formation of crevasses and irregularly directed chasms in the zone above. This accords with Russell's statement that * "The ice of glaciers is also broken along planes more or less inclined to their surfaces. Movement takes place along these cracks, and produces thrusts, analogous to the over-thrusts, or under-thrusts, sometimes seen in rocks that have been folded and broken. In fact, the counterpart of many of the structural features observed in rocks, such as faults, folds, joints, contortions, etc., may be observed in the ice of glaciers."

Mention has been made by various writers of the movement upward in portions of some glaciers, as, for example, where Prof. Pfaff noted in one of the reservoirs of the Aletsch glacier, where the surface slope was 9° , that the direction of motion made an angle of about 40° with the horizontal. Some

*Glaciers of North America, 1897, p. 11.

authorities have doubted the validity of such observations, but it does not seem improbable that they were quite correct nevertheless. In the zone of constant plasticity, to be considered, the direction of flow would naturally be in the direction of least resistance, so that if a land barrier were interposed in the natural path of movement, or the slope of the bed were reversed in direction, the resultant of the two pressure components might readily force the ice upward and raise the mass above it. It is even possible that a large mass of the lower portion of the glacier would pass into the zone of fracture, carrying with it the morainic debris from the bed beneath, which in time would be extruded from the central portion of the ice wall at its melting terminus.

It has been suggested that the comparatively rapid rate of motion of the Arctic glaciers may be due in part to the presence of infra-glacial material; it would appear, however, that its aid is small, and the rapid rate of flow is to be more particularly attributed to the great amount of ice in the zone of constant plasticity. Here the movement would be chiefly in this zone rather than in the zone of fracture. It would be relatively rapid because of its increased mobility, carrying forward the whole ice mass, as an inundation, as previously noted. The power to erode is at the same time relatively increased, since the kinetic energy of the moving mass is proportional to the square of the velocity, and thus the production of ground moraine is greatly augmented, but does not become great enough to cause stagnation of the glacier.

Ice which is at such depth that the weight of the superincumbent mass exceeds its yielding strength, or its ultimate strength, is in the zone of constant plasticity. This depth, as shown on previous pages, would be variable, though so far as present experiments indicate, would not be less on the average than 300 feet. In this zone the weight above is great enough to mash the ice and render it like soft wax, and toward the bottom of the larger glaciers the very slight increase in temperature resulting from the pressure, as shown elsewhere in this paper, doubtless aids in producing a condition of pure viscosity. This condition precludes at once the existence of cavities of any sort for the ice would flow in the path of least resistance, and immediately close them.

Viscosity is defined as *tangential force per unit area divided by shear per unit time*, and so the conditions for viscosity are here of the best. The force, due to pressure is enormous, and while the time is indeterminate, the shear resistance is certainly small for ice masses as shown by experiment. The modulus of elasticity is low * as would be expected, so that any small deformation produces permanent strain, resulting in a rearrangement of crystalline aggregates, if not indeed of the crystal molecules themselves. Thus it is obvious that in the zone of plasticity, continuous deformation of the ice mass results from the pressure exerted upon it, which pressure consists of both a vertical and a horizontal component. "Minerals deformed in the zones of flowage," says Van Hise, "show no interspaces under the microscope, but their remarkable shapes, undulatory extinction, and granulation in polarized light give evidence of their change of form." † And again "deformation may be partly accomplished by the rearrangement of the mineral particles with respect to one another." ‡

Such changes in ice crystals are apparently well exemplified by the studies of Deeley and Fletcher, mentioned previously. Furthermore it seems entirely probable that the ice in this zone is assisted in its movement as a viscous mass through the prime agencies of continuous solution and recrystallization. The great pressure exerted in this zone, which is at the same time widely variable in magnitude and direction because of the opening and closing of crevasses and irregular movements in the zone of fracture, together with temperature effects, is obviously a cause for a state of interior strain in the ice mass. It has been shown by Barus § that the work done in straining certain materials is largely potentialized, and, further, that in the case of glass || the release from strain occurred through the process of crystallization. Van Hise ¶ also says, concerning rock materials, that "as soon as a state of strain is produced, the processes of solution and recrystallization set to

*See Smithsonian Tables.

†Principles cit. p. 696.

‡Principles, cit. p. 694.

§The mechanism of solid viscosity, by Carl Barus. Bull. U. S. Geol. Survey, No. 94, 1892.

||The Compressibility of Liquids, by Carl Barus. Bull. U. S. Geol. No. 92, 1892.

¶Metamorphism of Rocks and Rock Flowage. Bull. of the Geol. Soc. of America, Vol. 9, p. 300.

work to adjust the minerals." Such a conception applied to ice necessarily precludes the possibility of obtaining a measure of the straining, because the strain is continuously obliterated by solution and recrystallization.

Yet it is easily shown that mechanical stresses in the ice mass are constantly operative, and a condition of strain it seems must inevitably exist. Again it has been shown that in general, in the process of recrystallization under condition of saturation, there is always a growth of large crystals at the expense of the smaller ones. This fact is due, as pointed out by Ostwald, * to the phenomenon of surface tension which exists on the boundary surfaces between solids and liquids. These surfaces are reduced in size by the tension, with the resulting enlargement of individual crystals, the process being augmented, as is well known, by pressure and increase in temperature. Now for a given volume of the substance it is easily seen that the surfaces of the crystals are inversely as their diameters, whence it appears that an increase in the size of the crystals, through the reduction of surface tension liberates energy as heat. It is difficult to estimate the amount of heat thus set free in the case of ice, but it would seem that this heat, be it great or small in amount, will aid the pressure in increasing further the rapidity of crystal growth.

The particular point of interest here is the possible application of these principles in explanation not only of the movement of the ice mass, but also of the well known fact that crystals of glacier ice increase in size in passing from the *nèvé* line toward the terminus of the glacier. If this assumption concerning solution and recrystallization be true of the zone of plasticity, the premises relating to the movement in the zone of fracture do not preclude its application there also, to a greater or less extent. Indeed it is probable that an increase in size of crystals takes place where the forces of rupture, solar energy, and regelation, are in active operation.

It is also logical to suppose that partial recovery from a state of strain where the deforming pressure is relieved, means partial recrystallization, in which case the bounding surface might in consequence be irregular and curved and the optical axes arranged at random, as instanced by Deeley and Fletcher already quoted.

*Foundations of Analytical Chemistry. W. Ostwald.

It should be said that possibly too few recorded experiments are available upon the properties of ice, and glacier ice in particular, for one to be able to reason in a perfectly logical manner concerning its behavior under the conditions extant in a glacier. It seems well, however, to consider what experimental results are given, remembering that conjecture alone must account for certain phenomena of a glacier, since some portions are quite as inaccessible even as the inner portion of the earth's crust. Such consideration leads to the assumption of the zones of fracture, and constant plasticity, together with the movements therein. Recorded observations appear to verify the reasoning, and to conform to a theory of glacier motion, which may include to some extent the causes of movements and deformation of the earth's crust.

The scope of this paper cannot include a presentation of such a theory in detail, and only a suggestion of certain principles is here attempted. It is believed by the writer, however, that a further study of the properties of glacier ice, including tensile and compressive strength, with proper curves to show the relation between strength and temperature, together with careful examination under the microscope and polariscope of the crystalline structure of different parts of a glacier should be made.

Further, the more prevalent use of the camera for the purpose of illustrating important features of scientific interest connected with glaciers, cannot fail to be commendable, and possibly may aid greatly in settling disputed questions. That photographic work is possible at the present time under almost any circumstances likely to be met with in glacier study is well known, and is most admirably evidenced by the eight hundred photographic reproductions in Peary's book on the Arctic region.

Advance and Retreat of Glaciers.

Early observation upon glaciers appeared to indicate an advance or a retreat with reference to the line of lower limit, corresponding with variations in precipitation and temperature of the air. Enlargement apparently took place in cold rainy periods of years, and diminution in the warm and dry. A report by Prof. Forel (1886) * shows that there ap-

*Am. Jour. of Science, Vol. 32, 1886, p. 77.

peared to be such periods in connection with the glaciers of the Alps, viz., enlargement from 1800 to 1815, diminution from 1815 to 1830, enlargement from 1830 to 1845, diminution from 1845 to 1875, and enlargement from 1875 onward. These periods are quoted by one of the text-books, yet it will be noticed that they are remarkably regular, and it would seem that sufficient study had not been given to the subject to warrant these conclusions. At a later date Prof. Forel * states that the periodicity of glacial variations is much longer than was formerly believed to be the case. "It is possible," he says, "that the cycle of variation is 35 to 50 years." Beginning with 1850 or 1855 the glaciers steadily decreased up to 1875. At that time they apparently began to increase again in the Mont Blanc region.

In a summary by Dr. H. F. Reid † concerning glaciers in 1899, the following statements are made:

"Swiss Alps.—As we approach the end of the century the advance of a number of glaciers which began in 1875 has gradually died out. Only one glacier was known to be advancing in 1899; nine were doubtful, and fifty-five were certainly or probably retreating." ‡

"Italian Alps.—Eight glaciers show retreat and two advance. The glaciers of the French, Swedish and Norwegian Alps are either stationary, or show a slight retreat. Photographs of the small Kiagtut glacier of Greenland show a retreat of several hundred meters between 1876 and 1899. The Victoria glacier near Lake Louise, Alberta, is retreating, and the Illecellewaet shows an average retreat since 1887 of about 15.8 meters per year. In Russian Asia the glaciers are retreating, while in the Himalayas the condition is more or less uncertain. It is probable that the majority are stationary or advancing slightly."

In the volume published by the U. S. Geol. Survey on "Explorations in Alaska" § it is shown that the Alaskan glaciers were formerly much more extensive than now, and show evidence of continued retreat. It is also indicated that Alaska was never under a continental ice sheet as was the eastern

*Am. Jour. of Science, Vol. 144, 1892, p. 342.

†Jour. of Geology, Vol. 9, 1901, pp. 250-254.

‡From report of Prof. Forel.

§Twentieth Annual Report U. S. Geol. Survey, Part 7, 1898.

part of North America. In a recent Russian report on the glaciers of the Caucasus mountains, of thirteen glaciers observed, all were retreating; those on the northern slope at the rate of 66 feet per year, those on the southern, at 75 feet per year.

Line of Lower Limit.

The line of lower limit of glaciers varies of course with the geographical location. In the Alps where the line of perpetual snow is fixed at about 7500 feet above sea level, the line of 32° is about 2000 feet; and the line of lower limit, about 5000 feet below the snow line. In some parts of the Arctic Region the 32° line is at an altitude of 3500 feet. In Norway, the line of lower limit is about 4000 feet below the 32° line. In Chili glaciers touch the sea level at 46° 40' south latitude. * The line of lower limit of perennial snow is about 2000 feet above the sea level in the Mt. St. Elias region, where so many glaciers become united in the great Malaspina glacier of the Piedmont type. This glacier has an average breadth of 20 to 25 miles, and an area of about 1500 square miles, or about midway between the states of Rhode Island and Delaware. This remarkable glacier will again be mentioned in connection with the subject of moraines.

Glacial Drainage.

Most of the Alpine glaciers are drained principally by streams issuing at their ends from beneath. It is worth noting that a feature of Greenland glaciers is that the character of drainage does not coincide with the drainage common to Alpine glaciers. "It is the rare exception," says Salisbury, of Greenland glaciers, "that a visible stream of any size issues from beneath a glacier at its end."†

The water that without doubt issues from the glaciers, passes through or under debris, rather than over it. The sides of a glacier, it is said, rarely rest against the valley, but usually have a stream between the ice wall and the side of the gorge. Very few streams are found on the ice surface, as the water plunges into the crevasses soon after formation. Occasionally englacial drainage takes place, and the water may issue in a great stream from the centre of a mass of ice at its

*Le Conte, text-book.
†Jour. of Geology, 1896.

end, and further, these streams sometimes contain silt which must have been raised from the bottom of the glacier.

Stratification.

Some observations on the stratification of glaciers have been made, though it is said that a correct observation of this phenomenon is very difficult. Prof. Heim* gives some attention to stratification, and Prof. H. F. Reid also gives a theory concerning it. † He says, "In order that the general volume of the glacier should be preserved we must have below the névé-line, where there is melting, a component of the motion toward the surface, and this component is strongest where the melting is greatest; i. e., it gets larger as we descend the dissipator. Above the névé-line this is reversed." The movement of a glacier is so related to its formation and surroundings that stratification is probable, though it seems that a thin layer of debris is almost absolutely necessary to determine the surfaces of separation.

Drawings made by Agassiz show such layers as he found them in the Unteraar glacier ‡ and they appear to be true surfaces of stratification. In some instances it is observed that rock material falling upon the snow in the cirque is carried along the under part of the glacier, reappearing at the surface near the terminus. Debris layers in the Sierra Nevada glaciers are cited by Prof. Russell§ as separating successive strata. "The parts of strata formed at a distance from rocky slopes have very little dust blown upon them, and consequently when they reappear at the surface in the upper regions of the dissipator the stratification is but slightly, if at all, indicated by dust bands. The strata should be well defined at the lower end, but the large amount of debris on the surface and in the crevasses, would make them difficult to recognize."||

A controversy existed between Agassiz and Forbes in 1841, as to the meaning of banded structure seen on the surface of glaciers. The former contending that such structure marks the outcrop of strata, while the latter believed it to be a peculiarity of glacier ice, and independent of stratification.

*Gletscherkunde.

†Jour. of Geology, 1896, Vol. 4, pp. 917 to 923.

‡Système Glaciare, p. 260, Atlas, plate 5.

§The glaciers of U. S. 5th Ann Rep. U. S. Geol. Surv. 1883-4.

||Mechanics of Glaciers. H. F. Reid. Jour. of Geol. 1896, Vol. 4.

Very little seems to be recorded on this point. The Mont Blanc glaciers recently studied by Dr. Reid, however, show blue bands well developed, and at the same time show conclusively that they are independent of stratification. In unweathered sections, he says, it is not difficult to distinguish between the blue bands and stratification, though after exposure to the weather they are so nearly alike that to distinguish between them is difficult.

Study of the Swiss glaciers by Deeley and Fletcher indicates that the névé when viewed from a distance appears to be finely stratified, having layers of blue ice alternating with white ones. Such stratification, however, on close examination appears to be due wholly to air bubbles imprisoned in the ice. And though the granules are known to have their optic axes arranged in no definite direction, yet "the lines of bubbles traverse the mass in definite layers." These layers of bubbles are shown to be the result of alternate melting snow at the surface, and falling of snow thereupon, thus imprisoning some air each time. This air is, of course, subjected to pressure by the accumulation of snow, and as the snow changes to névé and thence to ice, more or less air will be held between the granules. Meteorological conditions would naturally influence this volume of enclosed air, and it is found, for example, that the ice of the Grindelwald is very pure and blue, as compared with that of the Mont Blanc range. A massive ice-sheet, also, may have local eddies in its lower portions, the ice moving obliquely to the general flow of the main mass, as is well known in Greenland where it flows around the isolated Nunataks. * It there acquires in some cases, it is said, a beautiful banded structure. †

Erosion.

The erosive action of a glacier is a very distinguishing feature of ice action. The contact and pressure of the ice, doubtless aid very materially in dislodging boulders and rock material from the mountain surface, but by far the greater action is produced by the blocks of rock, stones and sand that find their way between the ice and bed over which it moves. Such detritus is angular in character and though it becomes

*Nansen. "First crossing of Greenland."

†Plates 9 and 11 of Paper on Greenland Ice, by E. von Drygalski, *Zeitsch. Gesell. f. Erdkunde*, Berlin, 1892.

reduced in size, retains its angular shape. Daubrée has shown * that the sand which appears at the end of an Alpine glacier is in the form of sharp broken grains, rather than that of water worn particles. Frequently the erosive rock material at the bottom of a glacier reaches its position by falling from the surface into the crevasses, as is evidenced notably by the Muir glacier. In the central part of this glacier most of the rock material falls into the crevasses. After a crevasse is formed, the sun melts back the north wall rapidly converting a broad ridge of ice into a sharp one, and thus causes the moraine load to be dropped in. Again the erosive material may fall into the narrow space that sometimes exists between the glacier and the sides of the valley. Geikie gives the Mer De Glace, Chamounix, as an example, † where he says, "Blocks of granite are jammed between the mural edge of the ice and the precipice of rock along which it moves, and which is scored and polished in the direction of motion of the blocks." Such material acting with the slow, continuous movement of the ice becomes an enormously powerful erosive agent, grinding down the hardest rocks until they are left in a polished, smooth or striated condition. Such striated rocks are often scored by deep grooves, as well as by fine lines made by quartz pebbles, and are frequently of an undulating or hummocky nature, in which case the well-known term *roches moutonnées* is given to them.

Erosive action is often valuable in determining the history of a given locality; e. g., the sides of the mountains bordering the Muir inlet are polished and striated with very fresh marks up to a height of 2000 feet, and above this altitude striae are occasionally seen up to 3500 feet. This indicates that the whole region must have been covered at an earlier date with a mass of ice wherein only the highest mountains projected through. Further, on the tops of all the low mountains bordering the Muir glacier over which ice has swept, diminutive lakes occur. All of them are small only a few yards across and not deep. "The conclusion cannot be avoided," says Cushing, "that these hollows are the work of ice."

It is to be remembered, however, that all debris charged glaciers do not necessarily produce important erosive results.

*"Geologic Exper." p. 254.

†Geikie, Text-book 1893, p. 428.

Whether a glacier charged at its base with debris shall erode or deposit at a given point, obviously depends upon its rate of flow. This rate of flow is influenced not only by the angle of slope, the pressure due to accumulation of snow and ice, and the configuration of the enclosing valley, but also to a great extent by the amount of englacial debris carried at or near the base. "If the debris charged ice moves at all it will cause abrasion;" says Russell * "but, if it is so heavily charged with debris that it is rigid under the forces to which it is subjected, it will remain stationary, and will not only cease to erode, but protect the rock beneath and lead to the accumulation of debris." Salisbury confirms this statement by his observations in the north where "the lower part of the ice carrying debris in large quantities, seems to be motionless, and to become a bed for the upper part of the ice mass to move upon." †

Running water is sometimes an important factor in erosion by Alpine glaciers. As the ice is melted during bright days, there appears a stream upon the upper surface which may attain a considerable size before reaching a crevasse and tumbling in as a water-fall. The sand, mud or stones carried by the stream will tumble in with it, and under certain conditions where the crevasse is a deep one, it may become still deeper and finally moulins are eroded in the bed rock. These moulins will naturally contain the rounded detritus after the crevasse at last closes up and the ice moves onward. Many cavities of this kind are found in Norway known as "giants' kettles," which have doubtless had an origin under the mass of ice which once overspread the country.

It seems that a comparatively small amount has been done on the matter of actual measurement of erosion by different glaciers, though some idea of the amount of erosion is obtained from the fine sediment which gives the characteristic turbidity to the streams that escape from the melting end of Alpine glaciers. It is stated that the Aar glacier, which is one of the smaller glaciers of Switzerland, discharges every day in the month of August 440 million gallons of water, which contains 280 tons of sand. ‡ The fine sand from one of the

*Journal of Geol. 1895.

†Journal of Geol. 1896.

‡Geikie, Text-book 3d edition.

Certain it is that the adjacent mountains are worn away, and the material is continually carried forward, and finally dropped, for the most part, at the end of the glacier in the form of terminal moraines. The mass of general evidence goes to show also that the amount of englacial debris of an Alpine glacier is, with few exceptions, relatively small compared with that moving upon and with the surface of the ice-mass.

This superficial morainic material divides itself in the case of Alpine glaciers, as is well known, into **three classes**: the lateral moraines; medial moraines; and terminal moraines. In the Polar ice-sheet another type of much importance is known as ground moraines. Lateral moraines result from the weathered material of the adjacent mountains falling upon the ice-mass, and distributing itself along the edges of the glacier. Wherever two tributary glaciers combine, it is readily seen that one lateral of each will combine with the other to form a medial moraine.

The lateral and medial moraines seem to **be particularly** important only in so far as they bear upon the disintegration of the mountains, and thus act as powerful abrasive and erosive agents, and possibly influence somewhat also the rate of flow of the glacier.

In some glaciers of the Piedmont type, however, the lateral moraines are of some moment. As a typical example the Malaspina glacier, previously referred to, is interesting. This plateau of ice about 1,500 feet high, is free from medial moraines, though broken over its surface by thousands of small crevasses. Moraines cover the border, however, and according to Russell, * they are all formed of the debris brought out of the mountains by the tributary Alpine glaciers, and concentrated at the surface by reason of the ablation of the ice. Some of the outer portions of the fringing moraines are covered with vegetation. Trees of cottonwood, alder, shrubs and ferns grow so densely as to prevent passage through them; and all on ice which in many places is not less than one thousand feet thick.

The classes of moraines that are of most importance are the terminal, and so-called ground moraines. A rather sharp

*I. C. Russell, *Am. Jour. of Science*, Vol. 143, 1892.

distinction exists between these two classes, depending upon the character of the material which is dropped, or extruded at the end of the glacier. The terminal moraine is composed of sharply angular blocks and fragments in the case of Alpine glaciers, as would be expected from the fact that the broken, angular mountain material has been carried chiefly upon the surface or the upper and median portions of the ice. The ground moraine on the other hand which is so largely exemplified in the Scandinavian and Greenland glaciers, consists of sub-angular and striated stones and water worn gravel, showing the detritus is infra and fluvio-glacial material.

Nansen and Chamberlin agree concerning the Greenland glaciers, that where no Nunataks occurred, no superficial detritus was visible; Chamberlin, as well as Salisbury, however, both evidence the fact that the lower strata of the ice is crowded with ground moraine, and turbid water escapes in great volume from the "inland ice." The question naturally presents itself, where does all this detritus come from? It is evident that it cannot come from the sides of mountains, as is the case in Alpine glaciers, but must come largely from the land beneath the glacier. It has been shown by observation (Prof. Heim) that a glacier is capable of fracturing and sundering projecting masses of schist over which it flows, and it follows by observation of ground moraine material, that the glacier itself not only abrades and smooths but also ruptures the rocks over which it moves; when the angle of slope and weight of the ice are sufficiently great, this is readily conceivable.

Continental Glaciers.

It is necessary to again refer to Agassiz, as the pioneer of glaciology, for the original conclusion that the northern portions of both continents have been covered with immense ice sheets. His efforts to prove the correctness of this opinion have been a great stimulus to others, who, since his time, have confirmed his views, and have shown that the ice sheet at the climax of the glacial period probably occupied an area of some 2,500,000 square miles. This mass of ice had a depth of from 1,350 feet on the northern slope of the mountains of Germany and 2,500 to 3,000 feet in Scotland, to 5,500 feet, even, in some of the Norwegian fjords. * In North America a

*James Geikie, 'Earth Sculpture,' pp. 232-233.

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similar and contemporaneous ice mass is evidenced, extending over Canada and the north-eastern United States, exhibiting the same characteristic work as that of the old world. The thickness of the ice is shown by the fact that the Catskill mountains are glaciated near their summits at a height of 3,000 feet. The White mountains are said to be ice worn at a height of 5,500 feet; * ice worn surfaces have been found in New South Wales at elevations between 4,000 and 6,000 feet; and Dawson speaks of glaciated surfaces in British Columbia at a height of 7,000 feet above the sea.†

Origin of the Ice-Age.

As to the *origin* of an Ice-age, which is a subject of great curiosity, if not, indeed, of supreme importance, the theories of eminent men are so at variance with each other, that it seems practically impossible to arrive at a satisfactory conclusion.

Geologists, astronomers, physicists, have vied with each other in the establishment of an infallible theory, but in view of the fact that the question is open for further efforts, the writer would in passing merely refer to a small part of the literature upon this point.‡

The leading causes of an ice age that have been propounded are well set forth in a series of papers on, "The Evolution of Climates," by Mardsen Manson.§ He enumerates them as follows:

1. A decrease in the original heat of the globe.
2. Changes in the elevation of the land, and consequent variations in the distribution of land and water.
3. Changes in the obliquity of the axis of the earth.

*Archibald Geikie, Text-book. pp. 1050.

†Geol. Mag. 1889, p. 351.

‡Sir Robert Ball, Nature, Vol. 25, 1881, pp. 79-103.

Darwin, Trans. Nature, Vol. 25, 1881.

Lord Kelvin, Trans. Geol. Soc., Glasgow, Vol. 5, p. 238.

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Lyell, Principles of Geology.

Sir John Herschell, Trans. Geol. Soc., Glasgow, Vol. 3, p. 293.

Dr. James Croll, Phil. Mag., Vol. 28, p. 121, also, Climate and Time, and Discussions on Climate and Cosmology.

A. Falsan and E. Chantre, Ancient Glaciers.

J. Partsch, Die Gletscher der Vorzeit in den Karpathen, 1882.

T. C. Chamberlin, Jour. of Geology, Vol. 7, 1899, pp. 545, 667, 751, Amer. Jour. of Sci.; Ann. Reports U. S. Geol. Survey; Bull. Geol. Soc. of America; Jour. of Geol.; and Amer. Geologist, for the last ten or fifteen years.

§Am. Geol., Vol. xxiv, pp. 93, 157, 205.

4. A period of greater moisture in the atmosphere.
5. Variations in the amount of heat radiated by the sun.
6. A variation in the heat absorbing power of the sun's atmosphere.
7. Variations in the temperature of space.
8. A coincidence of an aphelion winter with a period of maximum eccentricity of the earth's orbit.
9. A combination of Nos. 8 and 2.
10. Ball.—"The Cause of an Ice Age."

Dr. Croll's hypothesis appears to have done more to stimulate inquiry upon this question than any other, although it must be regarded at present as incompetent to satisfy all conditions required of it. For example, his theory demands the alternate glaciation of the Arctic and Antarctic regions, but geologists find no evidence of such alternation, while facts, however, go to show contemporaneous glaciation of these regions; again, ice scratches and grooves seem to be equally fresh in both hemispheres, so that it does not seem that there can be a difference of 20,000 years in their ages as required by the theory; and finally, the work done on the earth's surface since the ice passed away seems too little for the 80,000 years which Dr. Croll supposes to have elapsed since that time. The gorges of Niagara and St. Anthony support the view, it is claimed, that they are too small for the work of their streams during such a period. Geologists are more disposed from the array of facts thus far collected, to place the time since the cold era at 10,000 to 15,000 years, than to admit Croll's hypothesis.

It appears that the contest over the evidence of Quaternary glaciation was first developed concerning cold temperate latitudes, then for warm temperate regions, and has finally come to be confined largely to tropical countries.

In a paper on "The supposed glaciation of Brazil," by Branner, * this author refers to the controversy over the question, alluding to the fact that Agassiz and Hartt on first inspection of the country, believed it to have been glaciated. Prof. Shaler states it as his opinion, however, that Agassiz gave up the idea before his death. Branner says that in his eight years of travel and geological observation over the

**Jour. of Geol.* 1893.

country of Brazil, he did not see, "a single phenomenon in the way of boulders, gravels, clays, soils, surfaces, or topography that could be attributed to glaciation."

On the other hand Prof. T. G. Bonney * refers to the glaciers on Mount Kenia as significant. To quote his own words: "The extension of the glaciers on Mount Kenia (19,500 feet) is especially interesting, because its position (almost on the equator) suggests a possible refrigeration of the earth as a whole, rather than that of its hemispheres alternately." He adds in a foot note, however, that Dr. J. W. Gregory, the explorer of Kenia, was more favorable to the idea that the refrigeration was produced by an uprising of the region, and not by any general climatal change.

A paper by Upham, † recently published, elaborates to some length the "evidences of epeirogenic movements causing and terminating the Ice-age."

The paper by T. C. Chamberlin for which reference has been given, on "*An Attempt to Frame a Working Hypothesis of the Cause of Glacial Periods on an Atmospheric Basis*," is one of the most recent, and at the same time, perhaps, the most logical and profound of those that have been written. This hypothesis accounts admirably for the cause of the variations of climate, producing epochs of glaciation during Pleistocene time, by variations of the amount of carbon dioxide contained in the atmosphere. It has been calculated by the Swedish physicist Dr. Arrhenius (1896) that were the present content of CO₂ in the atmosphere to be reduced to an amount ranging from 55% to 67% the average temperature would fall 4 or 5 degrees C., and thus produce a glacial epoch; on the other hand an increase of the CO₂ by two or three times the present amount would raise the average temperature sufficiently to produce a mild climate in high latitudes.

Upon such a foundation for his theory, Professor Chamberlin has rigorously analyzed and discussed, so far as present knowledge permits, the rational causes of CO₂ depletion in the atmosphere, with its subsequent restoration thereto; and further the competency of such to produce oscillations of glaciation in accordance with the time limits set for

*"Ice-Work Present and Past." 1896.

†Bull. Geol. Soc. Am. 1899.

the probable glacial epochs, and the extension of glacier work during Pleistocene and Carboniferous times.

The efficiency of the agencies whereby carbon dioxide is withdrawn from and subsequently restored to the atmosphere, is shown to be correlated with geographic conditions, including the distribution of land and sea, and continental elevations. Since the geography of the earth in Paleozoic time is so imperfectly known, the hypothesis does not presume to so completely explain glaciation of that era, though the author presents and discusses such facts as are evident. To account for the depletion of the atmospheric carbon dioxide during this period, the locking up of the carbon as coal is considered most important, and it is shown that glaciation would result after a longer continued depletion had taken place, than was true of Pleistocene time. *

Work of the Ice Sheet.

The work of the great ice sheet as a powerful agent in shaping topography over portions of the globe appears to admit of division into two main parts: Erosion and Transportation.

The two parts are obviously more or less interlocked with each other, for erosion means transportation of material for at least some finite distance, and transportation is materially necessary to produce erosion. The division is here made, however, as covering the great results which are in evidence, and the two parts will be considered as such only in reference thereto.

In considering the subject of erosion by the ice sheet, it is well to consider first the work of the pure ice itself. Evidence is conclusive that it possesses little abrasive power, and practically no striating ability. It neither grooves nor scratches the bed rock, and can at most only very slightly wear it down.

It is obvious that whether widespread erosive results be considered to be due, as thought by some, to icebergs floating in a sea covering the areas in question, or due to the oscillations of a great ice mass over the surface, or both, the existence of a massive field of ice at some time is unquestionable. It is also probable that an irregularity of topographic conditions preceded the Glacial period, for there is no obvious reason why disintegration and decomposition by mechanical and chemical

*NOTE.—For an excellent brief review of Prof. Chamberlin's Paper, see "Climate and Carbonic Acid" by Bailey Willis, U. S. Geol. Surv., Pop. Sci. Mo. July, 1901.

forces respectively should not have obtained before the ice age as well as afterward. The resulting loose and weathered materials which were doubtless as voluminous as at present and possibly even more so, readily became occluded to some extent in the ice mass in such a way as to become a powerful erosive agent as the ice moved.

It is probable, also, in the light of recent investigation that many of the great rounded boulders that have been attributed specifically to ice action, are in reality the weathered products of pre-glacial time, which were simply transported by glacier ice.

The rock substance which was first gathered in by the ice may have been at first largely angular and jagged, but became worn and rounded by its action on similar material, as it moved onward rupturing, scoring, striating, and polishing the glacier bed. All the work was not done upon the bed, of course, for the higher topographic prominences must have been affected along their sides by the material of the surface portions of the ice mass. In this case the portions that were broken from the protruding rocks were either borne onward to the limit of the glacier flow or lodged at a more or less remote distance from the original rock. These transported fragments indicate, if different from the surrounding rocks of a given region, the direction of the former glacial movement. It is only by noting the position of such erratics, and the tracing out of their paths of transport by the glacier grooves and striae, often times over an extended area, that the massiveness and irresistible movement of the ice sheet is understood.

Erratic boulders of this character together with grooves and striae resulting from the erosive action of ice, indicate to an important extent the fact that certain regions of both the old world and the new world have been under a continental ice-mass, as in Greenland at the present time, and that there was much variation in the direction of motion, doubtless due to climatic conditions and underlying topography of the land.

It is evident that the grooves and striae so frequently observed upon rocks were produced in one or another of several ways which may here be briefly indicated.

First as to the grooves, it appears that they may in some cases have been pre-glacial in origin, and that the ice action was mainly that of a modifying agent. Again they may have been formed by the abrasive action of the rasping silt bearing glacial streams which always flow underneath and from the base of a glacier. Undoubtedly, however, many of the grooves are directly responsible to the debris-charged ice for their existence, and may be divided according to Chamberlin into two classes. "First, the grooves due to gouging tools, and, secondly, grooves due to exceptionally long continued or successive scoring. The former are usually limited in size and sharply defined, the latter wider and more vaguely delimited." The special gouging tools are materials such as granite and quartz, and the magnitude of the groove is dependent not only upon the character of the abrasive substance, but upon the pressure exerted and upon the relative hardness of the abraded surface. It is also obvious that not all original grooves in the softer rocks, and particularly those scorings of minor magnitude, would be in evidence at the present time because of the subsequent disintegrating agencies that have acted upon them.

The scorings have been divided into simple grooves and compound grooves. The former class represents the result of a single rock fragment, and it is worth noting that in such cases the cutting surface of this single fragment would be rapidly worn as well as the rock beneath, and give, as a result, a distinctly different appearance to the end of the groove where the work began from that where it ended. The second class supposes a series of abrading agents following approximately the same track in succession with the result that the grooves are broader, less regular, and more imperfectly defined. The simple grooves are thus the better indication of powerful glacier action.

Many examples of grooves produced by glacier force in America are recorded, among which in particular are those at Kelley's island, lake Erie; Amherst, Ohio; Victoria, B. C.; Cayuga lake, N. Y.; various places in New England; and in Nebraska. In the last mentioned state the grooves recently found in the rocks are said to be three inches across, and one and one-quarter inches deep.*

**Jour. of Geology.* 1900.

The striae so often referred to and so frequently found differ from grooves mainly in magnitude, though the abrading agents in this case are in general of finer character. The hair-like striae which are often sharply defined upon rocks, were probably produced by sand and silt acting not immediately beneath the glacier ice, but under the larger boulders moved along by it. Striae often present rough outlines, and vary in direction on the same surface, the latter being due either to a combination of movements of the abrasive materials during a given period, or to successive periods of glaciation. On the whole, however, taken in connection with the grooves they are a determinative factor in showing the direction of glacier flow, the markings generally being less prominent on the lee side of rock prominences than on the stoss side. This latter feature is amplified to a greater extent, however, in areas of less severe glaciation than in those where the erosive action has been powerful, for in the latter case the striating material has been crowded about obstacles, to a greater extent with consequent multidirectional scoring.

That the above is true is obvious on the basis of the theory of motion for Alpine glaciers previously considered. Where the glacier was of only average depth or less its relative rigidity was greatly increased because of the ice being largely in the zone of fracture, and consequently the plasticity of the mass relatively small, adjustment to underlying topographic conditions was but imperfectly made, with the result that scoring took place almost entirely in the general direction of the ice flow, and at the same time scarcely affected the lee side of rock prominences. On the other hand where the ice was of great depth the enormous weight caused the ice in the zone of plasticity to mold itself to every inequality of the ice floor, to fill all cracks and fissures, and to adjust itself to all topographic irregularities, and in so doing to carry with it the abrasive material in any or all directions irrespective of the general trend of the main ice movement.

In a paper published in 1888 Chamberlin states that there had been recorded about 2500 observations on drift striation in America, the same being made by 104 observers. * Of this

*For a very comprehensive treatment of this matter, see "The Rock-Scorings of the Great Ice Invasions," by T. C. Chamberlin, 7th Ann. Report of the Director of U. S. Geol. Survey, 1888.

number of observations 1666 are accredited to the New England states, New Hampshire standing first with 700. Of individual states other than those of New England, New York is first with 225, Ohio next with 154, then Pennsylvania, 147, and Wisconsin, 120. The difference in number of observations is shown to be due to several factors.

First, the irregularity of drift distribution is such that certain localities may have abundance of exposed rock surface, as in New England, while in others these surfaces are buried so far beneath the drift as to preclude observation.

Secondly, post-glacial decay of the scored rock surfaces has doubtless occurred in areas where the rocks were covered by a porous layer of material which admitted air and water.

Finally, unequal diligence in examination of rock surfaces, and unequal distinctness of scorings due to the texture and composition of certain rocks.

On the whole, however, the glacial marks are found to be more abundant in the northern portion of the drift area than in the southern, and are more prevalent and of greater magnitude north of the limiting moraines of the later epochs than south of them.

Turning now to similar phenomena in Europe it appears that striae were observed upon limestone as early as 1836, though little attention was given them until 1875 when their significance was pointed out by the Swedish geologist professor Otto Torell. Since then rock striae have been found in various places where the rocks are of a sufficiently hard nature to retain them. Owing to the chalky character of the rocks in Denmark and North Germany, one looks in vain there for rock striae, but north of this area, and farther south also these markings are more or less abundant. Such glaciated surfaces including polished roches moutonnees "prove that the great plain of Europe has been traversed by 'inland ice' flowing from Scandinavia and the Baltic." "Along the fjords of Norway," in the north also, says Geikie, "the ice worn surfaces may be seen slipping into the water, smooth, bare, polished, and grooved, as if the ice had only recently retreated."

The immense power of transportation by the ice sheet is perhaps best shown by the erratics, often of hundreds of tons weight, which have been moved in some cases for great distan-

ces, while its capacity for work, which brings in the time element prominently, is indicated by the vast amount of debris of finer material that has been removed from one locality and deposited in another as morainic formations. Some idea concerning the later factor will at once be gained by remembering the amount of material transported by some of the former glaciers in the Alpine lands, elsewhere considered, though continental glacier moraines are subsequently discussed. Concerning the movement of erratics Geikie says, "It is a fact that most, if not all, the erratics have traveled in directions that coincided with the trend of the rock striae." They are of all shapes and sizes and are found resting alike upon bare rock, angular debris, and morainic hills, having as a general rule been carried from higher to lower levels, though exceptions to the latter are sometimes found, the erratic being at a higher level than the parent rock formation. For example, Horne found granite erratics at a height of 2,764 feet, while the highest level of the granite *in place* was only 2,270 feet.*

These exceptions which are found both in Europe and America have been for glacialists a more or less puzzling problem to solve. Darwin, years ago, attempted an explanation on the supposition that these erratics were borne about by icebergs, which as the land sank down, dropped their burdens on higher and higher prominences of the drowning country. This belief became untenable soon after it was expounded, and the idea of deposition by land ice gained precedence first by Scandinavian geologists, and later by Forbes, Geikie, and others. Geikie says of a glacier transporting rocks imbedded in the ice mass, "A great deal will depend upon the boldness of the obstructions that impede the flow of the glacier. If these are numerous and formidable, then the lines of ejection will approximate more and more to the horizontal, and even at last curve upward, so as to dip *up* instead of *down* the valley; and thus boulders introduced into the ice at a given point will, as they are borne down the valley, not only rise, as it were, through the glacier, but eventually be extruded at a level which may be many feet, or even many yards, higher than the point in the valley from which they originally started."

This explanation is a most plausible one, for if we consider the enormous depth of the ice in some portions of the ice sheet,

*Geikie, *Great Ice Age*, 1894.

it is seen that the pressure exerted near the bottom is very great and an abrupt reverse of the general slope would readily produce, as noted for the Alpine glaciers, a movement toward the surface; in consequence, the boulders are moved upward into the zone of fracture, and in the specific cases under consideration doubtless the ice in the upper zone would be abnormally wrenched and shattered so that its density as a whole is much decreased. The boulder may thus be stranded upon the top of the obstacle opposing the glacier motion, and by the absorption of the sun's heat to a greater or less extent which would still further decrease the effect of the energy of the ice immediately around it, retain its position after the ice had finally disappeared. It is therefore quite conceivable that a boulder might start from the neider portion of a glacier and ultimately be found even hundreds of feet above its source. Frequently the boulders of this nature have a non-glacial aspect which is quite natural since they may have travelled in the ice mass without suffering any abrasion whatever. The point is well illustrated by the knapsack which was lost in a crevasse on the Telefre glacier on July 29th, 1836, and was disgorged by a coalescent glacier ten years later after having travelled in the ice a distance of over 4300 feet. *

The occurrence of immense erratics in America does not appear to be so prominent as in Europe, though several examples are known. The minor ones, however, have been very significant in determining the extent of drift over important areas.†

Another effect of both erosion and transportation is found over the tracts of retired ice sheets in the abundance of glacial lakes. Some of these clearly were formed by erosion as they lie in ice worn rock basins. Again where glacial detritus is prominent they rest in depressions formed by this material and their origin cannot be assigned to any influence other than that of the ice, either directly or indirectly. The character of the climate and natural conditions of topography influenced to an important extent the formation of such lakes. Northern Europe abounds with these lakes, the particular conditions as to the formation of which are well shown by Archibald Geikie, ‡

*Edin. Phil. Jour. 1847.

†Prelim. Paper on Driftless Area of the Upper Mississippi Valley. T. C. Chamberlin and R. D. Salisbury, 1886.

‡Text-book of Geology.

James Geikie, * and others. A magnificent example of a glacier excavated basin, though of comparatively small size, is that of Loch Lomond whose length is twenty-five miles and greatest width, about seven miles, with its surface twenty feet above the sea. It varies in depth quite uniformly from a few feet over its broader extremity, to three hundred feet in its narrower portion toward the opposite extremity.† It is said that all the existing great lakes between the United States and Canada, and perhaps those of northwestern Canada are bordered by deposits which indicate their former extension. The largest of all the glacial lakes in America has been called lake Agassiz. It occupied the basin of the Red River of the North and lake Winnipeg, having a computed area of about 110,000 square miles.‡

In some cases the advance of the ice sheet has marked its own limits in a very definite way by the rigid accumulation of material at its edges known as moraines. These are especially prominent in connection with later advances of the ice, and traverse the interior in America, in looped courses, such that the term interlobate moraines has been given to parts of them.

It is evident that this great continental glacier in its action upon the more elevated portions of the area over which it extended reduced such portions and transferred the detritus to lower levels. When the ice melted the accumulation of earth material, in what is designated as till, boulder-clay, ground moraine, terminal moraine, et cetera, and which has been instrumental in producing smoothed and striated surfaces, was left as the valuable witness of the ice work. This material known as a whole as "glacial drift," was deposited very unevenly and irregularly over the glaciated area.

The northern central states offer a peculiarly interesting and instructive field for a careful study of this subject. They embrace areas overspread with glacial drift, as well as the driftless territory, which is perfectly free from such material. This latter non-glaciated area of about 10,000 square miles in Wisconsin and adjoining states is most remarkable because it stands in the midst of a vast tract overspread with drift on all sides.

*Great Ice Age.

†Geikie, Great Ice Age (Appendix).
v. 1896.

‡See 'Glacial Lake Agassiz,' Upham, Monograph 25, U. S. Geol. Sur-

and yet in a veritable valley region of the Mississippi. The region has been known and studied for more than half a century and has afforded glaciologists a most direct means of attacking the great problems of continental glacier work and drift classification; * it is chiefly the results of an investigation of the region immediately south west of the great lakes, which has led to the belief in at least five distinct divisions of the drift.

Both in America and Europe the glacial accumulations show conclusive evidence of climatic oscillations, resulting in several distinct epochs. Professor Chamberlin has shown that the drift may be divided as follows: "Wisconsin Till Sheets (earlier and later); Interglacial deposits (Toronto perhaps); Iowan Till sheet; Interglacial deposit; Illinois Till sheet (Leverett); Interglacial deposit (Buchanan, Calvin); Kansan Till sheet; Aftonian beds, interglacial; Albertan Drift sheet (Dawson)

Geikie recognizes in the glaciation of Europe six epochs, though the last two were quite insignificant compared with the others. He says, "From the Pleiocene down to the close of Pleistocene times we have the record of a continuous series of geographical and climatic changes. Early in the cycle the glacial and interglacial phases attained their extreme development. The climax once passed, each successive cold and genial epoch declined in importance. In a word, the climatic and geographical changes became less and less marked as the cycle drew to a close."

The greatest of all drift deposits, the glacial till, was doubtless mainly deposited under the thinned edge of the ice mass. It consists of a great sheet of heterogeneously intermixed boulders, gravel, sand, and clay, which is more or less firmly compacted according to local conditions and parental origin, with which is usually associated more or less stratified material. The component rock fragments are usually rounded, and sometimes polished and striated.

Another form of till has been recognized as overlying the so-called true till. Such has been regarded by some as the deposit of englacial or superglacial material, because of its looseness, angularity of rock fragments, porosity at the base, and higher oxide of iron compounds, and is thought to have been dropped at the time of final melting of the ice, upon the true sub-glacial till.

*See Preliminary Paper on the Driftless Area of the Upper Mississippi Valley, by T. C. Chamberlin and R. D. Salisbury. Ann. Report U. S. Geol. Survey, 1884-85.

Another class of drift material has a somewhat remarkable occurrence as long sinuous ridges, known in Scotland as kames, in Ireland as eskers, and in Scandinavia, as osar, which consist sometimes of boulders and conglomerate detritus, but more often of more or less stratified gravel and sand, their general course corresponding to the direction of glacial striation, with the layers frequently declining toward the south. The term Osar, Asar, or Eskers has been more particularly applied to these forms in American literature, reserving the term Kame to especially define the conical hills, inverted bowl-shaped prominences, and short ridges that usually abound in the vicinity of terminal moraines, and stand "transverse to the course of the valley and the direction of drift movement."

Both eskers and kame, are presumed to be due to practically, the same influence, namely that of running water in connection with ice movement, though such is in all respects not perfectly conclusive. A study of the Malaspina glacier by Prof. Russell has resulted in the observation of Asar in process of formation. These are shown to be of glacio-fluvial origin, and formed in accordance with accepted theories for the production of those of the ice sheet.*

The American eskers are said to be essentially similar to the Asar of Sweden, and are exceptionally well developed in New England, and particularly so in Maine where they have been carefully studied by Stone.† Over thirty separate systems have been worked out in that state, two of the longer ones, the Katahdin, and Sebouis-Kingman-Columbia systems being each about 125 miles in length. Eskers also occur in the middle states and sparingly in Canada. Kames are very abundant in America associated with the terminal moraines from the Atlantic through the western states, and have been with the eskers carefully studied.‡

The appearance of the topography in regions where eskers and kames are numerous is that of a complex and irregularly distributed arrangement of hills of more or less gracefully

**Jour. of Geol.*, 1893.

†See paper "The Kames of Maine," *Proc. A. A. A. S.*, 1880, also "The Glacial Gravels of Maine and their Associated Deposits," *U. S. Geol. Survey, Monograph 34*, 1899. George H. Stone.

‡For a part of the more recent literature on the subject see, N. S. Shaler, *Proc. Boston Soc. Nat. Hist.*, Vol. 23, 1884; Ninth Annual report, *U. S. Geol. Survey*, 1887-88; W. O. Crosby, *Physical History of Boston Basin*, 1889; R. D. Salisbury, *Ann. Rept. of New Jersey Geol. Surv.*, 1891; I. C. Russell, *Amer. Geol.*, Vol. 12, 1893; W. M. Davis, *Bull. Geol. Soc. Amer.*, Vol. 1.

rounded contour. These embrace almost every form of mounds, knolls, hummocks, and serpentine ridges, frequently interspersed with depressions of a striking character and known by a variety of names as "kettle-holes, "sinks," et cetera. These depressions, of variable depth and area, and from a few feet to a hundred feet across, are not infrequently partially filled with water in such a way as to lend to the general topography a very distinctive and charming appearance.

In many cases a form of deposit is recognized as 'valley drift' which represents the overwash from a terminal moraine, and consists chiefly of a plain of stratified gravel. At a greater distance from the moraine is found the finer material which naturally would be held in suspension for a longer time by the glacial streams. The deposits like the fluvial deposits of loess in the Mississippi valley are of such origin. It is thought probable, however, that some of the loess deposits of this and other regions are only indirectly due to glacier action, having been deposited by winds acting on glacio-fluvial material.

In both Europe and America the glacial deposits increase in thickness and variety from South to North. The most recent of the two terminal moraines in America begins on the Atlantic border of Massachusetts where it is in part submerged, rises to prominence in Nantucket island, Martha's Vineyard, and Block Island whence it is prolonged to Long Island, there reaching a height of 200 or 300 feet. Another line of drift hills passes along the northern part of Long Island, embraces Fisher's island, and the southern end of the state of Rhode Island, thence to the Elizabeth islands and on into the state of Massachusetts. From the western end of Long Island the moraine passes across Staten island and northern New Jersey into Pennsylvania; thence northwesterly across that state and a part of New York, whence it turns to the southwest and again enters Pennsylvania, and passes on into Ohio, extending across the central part of that state and Indiana. Thence it takes a northwesterly direction crossing parts of Illinois, Wisconsin, and Minnesota, dipping into the center of Iowa as far south as Des Moines, and thence passing over Dakota into the British possessions. A summary by professor Chamberlin * shows that this morainic belt characteristically persists over a course

*Preliminary Paper on the Terminal Moraine, 3d Ann. Rept., U. S. Geol. Survey, 1883.

of three thousand miles, and forms one of the most extensive moraines in the world.

The older drift formation, or series of formations, than the moraine above cited, is in evidence at its easternmost point in southwestern Ohio, and reaches its southernmost limit near the junction of the Mississippi and Ohio rivers. Thence it continues northwestward following approximately the course of the Missouri river, and always passing under the more recent formation on the north. It is noticeable moreover, that the southern border of this drift area in both the earlier and later formations, presents a distinctly lobate appearance, the earlier stages being less pronounced than the later.*

A form of glacial prominence which is often associated with terminal moraine formations is known as drums, or drumlins. These most frequently consist of unassorted drift, though some are shown to be composed chiefly of boulder-clay; in some cases they are stratified near the base, and not a few, as pointed out by professor Shaler, have nuclei of solid rock. The typical form is lenticular, grading into elongated or elliptical mounds whose major axes extend in the direction of movement of the ice sheet. The origin of these forms does not appear to be perfectly comprehended, though in a general way they are classed as ground moraine formations.

A famous locality for drumlins is New England, where in Boston harbor, and neighboring parts of Massachusetts the typical lenticular form is well exhibited. They occur also in New York between Batavia and Rochester, and between Lockport and Niagara falls. The most extensive drumlin area, however, is probably that of eastern Wisconsin, which has been estimated by Buell to contain 10,000 drumlins. "All these tracts of pronounced drumlins," says Chamberlin, "lie north of the chief belt of terminal moraines and evidently belong to the later glaciation."

Geikie says of the drumlins of Scotland, "In the central portion of a broad Lowland valley, where superficial accumulations are thickest, the drums are invariably composed of boulder-clay alone. Toward the sides of the valley, however, where the till is thinner, the 'drums' occasionally show a core or nu-

*Map of the Glacial Striae of the Eastern United States—Rock Scorings of the Great Ice Invasions, 7th Ann. Rept. of U. S. Geol. Survey, 1888.

cleus of solid rock." On the island of Rugen in the Baltic, the drumlins are said to frequently have a nucleus of Chalk rock, while sand and gravel is often associated with the boulder-clay.*

It is not within the scope of this paper to discuss but briefly the location, or specific character of the existing glacial material, which necessarily has an important relation to the history of the topography of the globe; and also in special palaeolithic deposits bears directly upon the question of the existence of man during former geological periods.† A consideration of further important details must therefore be deferred until a future time.

The results of investigation which is constantly going on in the subject of glaciology can scarcely be predicted, for it is receiving much attention. Certain it is that the ice-sheet has greatly modified the original topography, both by its erosive effect and by the thousands of square miles of detritus which it scattered over different parts of the globe. This powerful agent together with subsequent ones of a warmer age, has been ever sculpturing the world's surface, and the world in its present physiographic form is simply the result of the conflict between the two great opposing forces: construction and destruction.

Furthermore, the ice age cannot be considered as a past epoch in the earth's history, since in polar latitudes glaciation is now going on at all altitudes; is also in progress in temperate climates at altitudes between 5,000 and 15,000 feet; and even in the torrid zone, at heights over 15,000 feet. As observation has shown that retreat of nearly all present glaciers is in progress, it is logical to conclude that the ice age is yet passing away, and that the earth has yet to reach the maximum temperature of the present geological cycle.

*Literature on drumlins, T. C. Chamberlin, *Geology of Wisconsin*, Vol. 1, 1883; *Ann. Rept. U. S. Geol. Surv.*, 1883; R. D. Salisbury, *Geol. Soc. of Am.*, 1891; G. H. Berlin, *Am. Geol.*, Vol. 13, 1894; James Geikie, *Great Ice Age*.

†See Article by Prof. A. S. Packard, "An afternoon at Chelles and the earliest evidences of human industry in France," *Pop. Sci. Mo.*, May, 1902.

EDITORIAL COMMENT.

WAS THE DEVELOPMENT THEORY INFLUENCED BY THE "VESTIGES OF THE NATURAL HISTORY OF CREATION?"

In weighing the claims of Charles Robert Darwin to the admiration of the world for his share in the construction of a rational theory to account for the common origin of the widely different forms of organic life, credit has been given to Democritus, Aristotle, Harvey, Wolff, VanBär, Remak, Buffon, Lamarck, Erasmus Darwin, Malthus, and even Bonet and Haller, for thoughts which served the great naturalist as building stones, or connective mortar. Now it is evident that the successful establishment of this great conception of the "Origin of Species" demanded preliminarily the winning of two separate victories of equal importance over deep rooted prejudices. These were compelling the assent of the reason of mankind first to the admission of the overwhelming evidence of the close relation of species in time and place; and second to the equally strong proof of the constant variations in progeny of the same parents, and of the ability of the possessors of special features to transmit these hereditarily when useful to the existence of their offspring. In default of forcing a conviction of the first proposition the second would be barren of interest. For this reason it is surprising that the influence of the "Vestiges of the Natural History of Creation," which appeared anonymously in 1845, should be so rarely and slightly alluded to (if not entirely ignored) by masters like Huxley and Haeckel who have moulded modern thought on this problem.

It is a fact that this excited immense interest at the time of its publication, running through five editions in little over a year, and drew down upon the head of its author much of the pompous and stilted malediction of the ponderous reviewers which would otherwise have been added to that which Darwin had to bear fifteen years later, had not the fatuity of many of the suppositious objections to the "Vestiges" by one reviewer been refuted by the others. As a lightning rod which discharged an enormous amount of destructive rhetorical electricity it cleared the atmosphere somewhat for the appearance of the greater work, but its ser-

vice was not confined to this. In clear and temperate English it marshalled such facts as were at the disposal of the science of that day into a clear and convincing proof of the development of all the material and mental phenomena of our world from previous existences, which diminished in number and variation as they were traced backward. Even the great thought which compared the progressive multiplication and variation of organic beings to the branching out of kingdoms, classes and orders from the parent stem of life is fully and lucidly expressed.

That the whole work is pervaded by a devout and reverential spirit should not lessen its influence, and that some grotesque errors are found cited as scientific facts should not condemn its work as a whole. The argument of this work, as resumed in the admirable reply to his critics and detractors printed in 1846, "is to show that the whole revelation of the work of God presented to our senses and reason is a system based in what we are compelled, for want of a better term to call Law" * * * "a system" * * "which only proposes a certain mode of his working" * * "while the whole physical arrangement of the universe was placed under law by the discoveries of Kepler and Newton there was still such a *mysterious conception* of the origin of organic nature" * * "that men were almost forced to make large exceptions from any proposed plan of universal order." * * "My starting point was a statement of the arrangements of the bodies in space with a hypothesis respecting the mode in which those arrangements had been effected." * * * After quoting M. Quetelet 'Sur l'homme, et le developpement de ses Facultes' to show that deaths, crimes, stature, weight, strength, etc., are shown by statistics to be amenable to natural laws, though individually appearing so discordant, he resumes "Now we have here two remarkable truths. The wondrous masses which people the mighty void are under the control of natural law. The working of the little world of the human mind—the opposite extreme of the system—are under law likewise." * * * "Can it" (not) "be that as the first and last parts of the system are under law" * * "so the whole is under law." He then deduces from the character of the successive formations of the earth's crust and their contents the gradual progression from the simplest to the highest forms of animal and plant life. P. F.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

Pleistocene Geology of Western New York. Report of Progress for 1900. By H. L. FAIRCHILD. Reprinted from the 20th Report of the New York State Geologist, 1900. Pages 1105-1139, with plates 9-41. Albany, 1902.

During several preceding years the glacial lake history of western New York had been studied by Prof. Fairchild, with extensive field explorations in the district of the Finger Lakes and in the Genesee valley, as previously published in numerous papers. The present report gives details of the continuation of these studies in three additional districts, first, along the Iroquois shore line, east of lake Ontario, between Richland and Watertown; second, between Syracuse and Oneida, with special reference to the higher and earlier channels cut by the overflow of the glacial waters; and, third, in Cattaraugus and Chautauqua counties, west of the former explorations.

With the grand work of detailed drift surveys by Leverett upon the region of lakes Erie, Huron, and Michigan, the less complete but very valuable work of Taylor and Lawson about lake Superior, and the report by the present reviewer on the glacial lake Agassiz, a most important part of the record of the recession of the ice-sheet from the northern border of the United States and from southern Canada is being well traced and correlated. Nowhere else upon all this vast area of great lakes dammed by the barrier of the departing continental glacier are the evidences of these lakes, small and large, with varying dimensions, changes of outlets, successive shore lines at different heights, contemporary or closely subsequent uplifts of the land, giving gentle slopes to the once level beaches, and all the relations of the lakes to the waning ice-sheet, so fully and complexly developed as in New York.

It is delightful to see in this report a large map of lake Iroquois, on the scale of 12 miles to an inch, and a map of its eastern shore lines for thirty miles on the scale of a mile to an inch. The warping, or differential uplift, of the east end of the Iroquois or lake Ontario basin is found to have occurred mostly after this glacial lake fell away from its Rome outlet, when, by extension around the north side of the Adirondacks, it became united with the glacial lake Hudson-Champlain and later became a part of the more extended but lower lake St. Lawrence. The tilting between Rome and Watertown, giving an ascent of fully five feet per mile along that distance of more than 50 miles, took place evidently at a much faster rate than the slight deformation of the region of the Laurentian lakes which has been ascertained by Gilbert to be still in progress, its present rate being .42 of a foot in 100 miles in 100 years.

The many plate views from photographs, showing the old shore lines and deltas, abandoned channels of outflow, and small lakes now existing in basins produced by stream plunge in the course of the ancient outlets, are very impressive testimony of an order of events in the Late

Glacial geology of New York, which is so marvelous that it could never have been imagined until discovered by painstaking and persevering field work. W. U.

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The Lansing skeleton. (Am. Geol., vol. 30, pp. 189-194, Sep., 1902. [Ed. Com.])

CORRESPONDENCE.

A CARBONIFEROUS COAL IN ARIZONA. The fact of the existence of a small deposit of anthracite coal in the Chiracahua mountains, Cochise county, Arizona, has been known for some years, but it is so disturbed by faulting and by the intrusion of eruptive materials that no practical use has ever been made of it.

Having occasion to visit this range of mountains in July I made it convenient to go by the old prospect holes. Upon examination I was surprised to find that it did not belong to the Triassic as I had always supposed, but it was overlain by beds of limestone of the Upper Carboniferous.

In a record of a former trip to these mountains* I noted the occurrence of the Upper Carboniferous thus:

"In the Chirachua mountains, on Cave creek, above Mr. Reed's house, we found exposures of platy limestones closely resembling those at the base of these beds.

"North of this, between Cave creek and Turkey creek, the exposures of Carboniferous limestones are very satisfactory. They dip SW from 30° to 45°; and the section is repeated by the occurrence of faults.

"The upper limestone appears to have a thickness of 1200 feet, and is underlain by 300 feet of limy clays with interbedded limestones. Fossils are abundant; but, as is the case throughout this area, they are all siliceous pseudomorphs, and are not well preserved. Dr. Schuchert determined the following species: *Syringopora multattenuata*, *Campophyllum torquium* (?); *Lophophyllum proliferum*; *Reticularia perplexa*; *Diclasma bovidens*; *Seminula argentea*; *Euomphalus subquadratus*; *Meckella striatacostata*; and fragments of *Productus*, *Spirifer*, and *Derbya*; so that the horizon is established as Upper Carboniferous. There appears to be a slight unconformity near the middle of the beds, but it may be due to faulting or slipping."

Although there is considerable faulting I found a clean section showing that the coal occurs in clays and slates which I did not find exposed on my first trip and which underlie the beds above described.

I also found the Triassic beds in their proper position far above this horizon, so there can be no question as to the Carboniferous age of this particular coal deposit.

While it may be that this deposit has no commercial value, its occurrence is of scientific interest as showing that conditions suitable for the formation of coal existed during the period of the Upper Carboniferous at a great distance to the west of any previously recorded locality.

E. T. DUMBLE.

Houston, Texas, Aug. 12, 1902.

*"Notes on the Geology of Southeastern Arizona." *Trans. Am. Inst. Min. Eng.* Vol. xxxi.

PERSONAL AND SCIENTIFIC NEWS.

DR. E. HAANEL, lately of Syracuse University, is superintendent of mines for the Dominion of Canada.

DR. C. R. KEYES, of Des Moines, has accepted the position of president of the New Mexico School of Mines at Socorro.

ADDRESSES AT THE LATE CENTENARY of the birth of Hugh Miller, at Cromarty, were given by Archibald Geikie, John M. Clarke and others.

PROF. A. LACROIX, of the Museum d' Histoire Naturelle will soon leave Paris for Martinique for the purpose of making a thorough examination of the recent eruption of Mont Pelée.

PROF. W. O. CROSBY AND MR. IRVING ADAMS recently returned to Cambridge after a summer spent in geological work in the Rocky mountain region, calling at Minneapolis and St. Paul en route.

THE LOCALITY OF THE LANSING SKELETON was recently visited by Profs. W. H. Holmes, of Washington; T. C. Chamberlin and R. D. Salisbury, of Chicago, and S. Calvin, of Iowa City, Iowa.

MR. E. O. ULRICH, ASSISTED BY MR. W. S. TANGIER SMITH is engaged in an examination of several counties in western Kentucky for the United States Geological Survey, with special reference to the known deposits of zinc, lead and fluorspar.

PROF. F. W. MCNAIR, president of the Michigan College of mines, is engaged with Dr. J. F. Harford, of the U. S. Coast and Geodetic Survey, in experiments at the shaft of the Tamarack mine, Calumet, Mich., designed to determine the density of the earth.

DR. W. J. MCGEE was elected president of the newly established American Anthropological Association, and George A. Dorsey, secretary. The next regular meeting will be held at Washington in connection with the winter meeting of the American Association for the advancement of Science, Dec. 29 to Jan. 3, 1903.

COLUMBIA UNIVERSITY, GEOLOGICAL DEPARTMENT. PROFESSOR GRABAU recently spent a week in southern Wisconsin examining the Hamilton beds of Milwaukee and Niagara beds of that vicinity. In company with state geologist Lane, F. B. Taylor, of the U. S. G. S., and Mr. H. P. Parnelee, of Charlevoix, a week was spent in exploring the Beaver Island group.

MR. D. W. JOHNSON, fellow in geology, has passed two months in the study of the Cerrillos mountains, New Mexico. Professor Kemp recently accompanied him for a week in the

field, and the party greatly enjoyed a visit from President W. G. Tight, of the University of New Mexico, and profited by Pres. Tight's knowledge of the physiography.

THE AMERICAN INSTITUTE OF MINING ENGINEERS will hold its eighty-third meeting at New Haven, Connecticut, beginning on Tuesday evening, October 14th. Among the important features of the program are: opportunity for inspection of the new bi-centennial buildings of Yale University, and also the plant of the Sheffield Scientific School, including Yale Forest School; excursions to points of geological, historical and scenic interest in the vicinity of New Haven; a biographic notice of the late Clarence King, prepared jointly by a number of his friends and associates. Louis V. Pirrson, 137 Wall St., New Haven, is secretary of the local committee.

MAJOR J. W. POWELL, DIRECTOR OF THE BUREAU OF ETHNOLOGY of the Smithsonian Institution and formerly Director of the United States Geological Survey, died at his summer residence in Hayen, Maine, at six o'clock on the afternoon of September 23.

Funeral services were held at his late home in Washington Friday afternoon, September 26, the interment taking place in the National Cemetery at Arlington. The active pallbearers were Messrs. J. K. Hillers, W. H. Holmes, H. C. Rizer, J. D. McChesney, G. K. Gilbert, and Cyrus Thomas.

The honorary pallbearers were C. D. Walcott, representing the Geological Survey; Charles J. Bell, the National Geographical Society; Edward M. Gallaudet; W. J. McGee, the Bureau of Ethnology; Wm. T. Harris, the Bureau of Education; George M. Sternberg, the Cosmos Club; Herbert Ogden the Coast and Geodetic Survey; W. F. Hillebrand, the American Chemical Society; Frank L. Campbell, Assistant Secretary of the Interior; D. C. Gilman, the Carnegie Institution; Marcus Baker, the Geographical and Historical Societies; Frank Baker, the Anthropological Society; Martin F. Morris, the Literary Society; C. W. Hayes, the Geological Society of America; Richard Rathbun, the Philosophical Society; Wm. B. Clark, the Johns Hopkins University; J. McBride Sterrett, the Columbian University; A. W. Greely, the United States Army; W. H. Dall, the Biological Society; W. P. Hepburn, and a committee of the Loyal Legion.

Memorial services were held in the lecture room of the National Museum on Friday afternoon, where the customary resolutions were passed and remarks by Richard Rathbun, the Assistant Secretary of the Smithsonian Institution; Dr. W. H. Dall; Dr. D. C. Gilman; C. D. Walcott, of the Geological Survey; W. T. Harris; Marcus Baker; and W. J. McGee.



Fig. 1. *Cladoselache fylleri*, showing fossilized muscle bands. The margin of the trunk passes vertically through the middle of the figure; part of a pectoral fin appears at the right, its hinder rim made more prominent by a row of black dots. Nearly natural size.



Fig. 2. *Cladoselache fylleri*. Section of muscle band photographed under a low power, showing outlines of fibres.

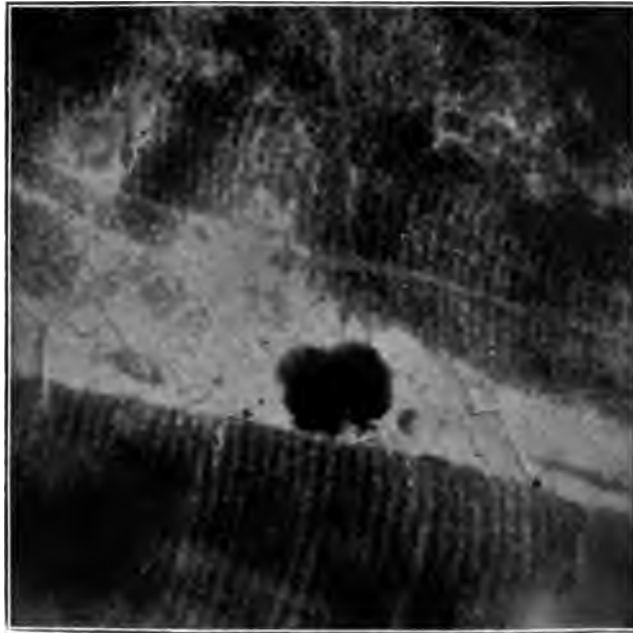


Fig. 3. *Cladoselache fylleri*. Muscle fibre detail, showing transverse striature. x about 1000.



Fig. 4. *Heterodontus japonicus*. Muscle fibre detail, showing transverse striature. x about 1000.

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No. 5.

THE PRESERVATION OF MUSCLE-FIBRES IN
SHARKS OF THE CLEVELAND SHALE.

By BASHFORD DEAN, Columbia University, New York.

PLATES VIII AND IX.

In fossils of vertebrates, fragmentary as they are, soft parts are sometimes preserved with startling clearness. Muscles and integumental webs are well known in a number of groups, and the student of palæanatomy has even collected convincing data regarding the nature of such frail organs as soft-walled viscera and spinal cord. Muscles, especially, are apt to be well preserved, even to the details of their individual fibres.

Favorable instances of the fossilization of muscle fibres are by no means uncommon in the fishes of the lithographic stone, as Reis has pointed out. Here in the case of the ganoid *Undina*,* he has described the fibres and their "reizende Striation," as so well preserved as to give an "ideale Bild der Muskelstructur,"—although this optimistic conclusion may not be shared by a reader on account of Reis's indifferent figures. And even in less finely grained sedimentary rocks examples are not lacking, both here and abroad, of well preserved soft tissues. In the case of an American matrix the Cleveland shale deserves especial mention, since it will no doubt provide many important facts regarding the intimate characters of the Devonian vertebrates. The reader may recall, for example, that it was in this shale that Newberry† first suggested the preservation of trans-

*Die Coelacanthinen, m. bes. Berücks. d. Gatt. d. weiss. Jura Bayerns. *Palæontographica*. Bd. XXXV, Taf. II.

†Mon. XVI. U. S. Geolog. Surv.

verse muscles in specimens of the remarkable cladodont sharks (*Cladoselache*).

The strikingly preserved tissue in these specimens had long been known to the present writer; but it was only recently, while re-examining the structures of cladoselachids, that he caused favorable fragments of it to be microsectioned. The material was then found so well preserved that he was led to prepare the following notes upon it, illustrated by photomicrographs. The latter were taken by his colleague, Dr. Edward Leaming, to whose generous aid,—in this as in similar instances,—the writer is greatly indebted.

It may be said, in passing, that the specimens of *Cladoselache* referred to by Newberry are of exceptional value to one who is studying fossilization as well as palæanatomy; thus in the type of *C. kepleri*, gill filaments are reproduced distinctly; and in several specimens the mineralized muscle bands, sometimes in patches several inches in length, are so well preserved that they suggest in color, distinctness and texture, the mummified tissue of recent fish. Pl. VIII. Fig. 1.*

The general appearance of the fossil muscle fibres is well shown in Pl. VIII, Fig. 2, from a photograph taken under a low power. One notes the crowded mass of cylindrical fibres whose outlines, in many cases clean-cut, suggest that the tissue at the time of its fossilization could not have been badly decomposed. Indeed, judging from Pl. IX, Fig. 3, in which a similar section is magnified about 1,000 diameters, one can conclude that the tissue was even in a very fair state of preservation, for, considering especially the fact that the fibres have undergone mineralization, the striae are still undistorted, and even what can reasonably be interpreted as bits of the sarcolemma (at the point * and *) are reproduced. These ancient muscle fibres, in fact, preserve the contours better, as it happens, than the fibres in recent tissue in the adjacent photograph, Pl. IX, Fig. 4, taken from a well preserved specimen of *Heterodontus*.

Comparing further the preparations (both magnified equally) of the Devonian and of the recent shark, we cannot fail to note the greater coarseness of the transverse striae in the ancient

*In the present figure (from a specimen of *C. kepleri*) there is shown also a portion of the characteristic Cladoselachian (pectoral) fin. Its web can be traced back along the side of the trunk in the line indicated by dots.



form. Here, in general, the striae are one-third, or thereabouts, less numerous. And I am accordingly inclined to believe, even taking into account the possibilities of the relaxed condition of the fibres, and of artifacts due to fossilization, that the ancient shark had not yet attained the high degree of muscular specialization of its modern kindred. This conclusion is materially strengthened by our knowledge of other primitive characters of cladodonts. (For summary v. *Natural Science*, 1896, vol. viii, pp. 247-253.)

Regarding now the process of the mineralization of such delicate structures as muscle fibres, interesting in a somewhat wider aspect paleontologically, Reis has written in considerable detail.* He finds that in lithographic stone fossils (and this will hold in a general way—t. Lankester and others—in the case of similar fossils from other rocks) the muscular mass is purely mineral, composed largely (80%) of calcium phosphate. On various grounds he concludes that the muscular tissue could have been but in a semi-decomposed condition (*halbfaulen Zustand*), that mineralization took place relatively quickly, and that the object must have been so completely and thickly enclosed as to prevent further disintegration. Unlike Owen, Reis maintains,—in this point, justly, it seems to me,—that the fossilization could not have been a part of or a sequel to a process of adipocere-making. He further concludes that the phosphate is derived from the body itself, product mainly of muscles and blood, precipitated when the decomposing material is brought in contact with the lime carbonate of the sediment of the sea bottom. As the petrified muscle has more phosphate in it than the recent tissue it follows, he maintains, that it has received the phosphate from the remaining muscles, and these, therefore, have not been preserved. In any event, final decomposition of such an organism takes place much more slowly in the deep sea than one is apt to believe, and there is thus a better chance for the gradual mineralization of tissues *i. e.*, by precipitation of lime.

The foregoing explanation covers the matter of delicate fossilization ingeniously, and in some ways satisfactorily. But in other regards it is, I think, open to serious objections. For,

*89 Ueber eine Art Fossilisation der Musculatur. *SB. Gesell. Morph. München*. DD. 6.

field, and the party greatly enjoyed a visit from President W. G. Tight, of the University of New Mexico, and profited by Pres. Tight's knowledge of the physiography.

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to enable a fish of smallish size, say of a foot or two in length, to sink into it naturally until partly or completely submerged. I say, sink into it naturally, for it is a well known fact that these sharks are in every case * preserved in the same position, ventro-dorsal, having sunken to the bottom doubtless with belly upward, still partly distended with gases. The bottom-sediment, accordingly, was soft and fine. It was also probably deep, since in some-cases the sharks have sunken into it completely, the well preserved fins passing out of the general plane of the fossil into an overlying portion of the matrix. Moreover the sediment could have been subject to no extensive movements, since these sharks, although collected over a wide area, show no evidence of having changed position (*i. e.*, rolled) from the time they first sank to the bottom.

Surface currents, on the contrary, may well have been present, since in the shale the remains of fishes with swim-bladders are conspicuously rare, in spite of strong evidence for believing that they must have been plentiful at that time, and even in that region (judging, *e. g.*, from the abundance of sharks and from their stomach contents). And we can best interpret their rarity in fossils as due to the presence of surface currents; for such types of fishes, unlike sharks,† would float during earlier stages of decomposition, and thus, on the assumption that currents were present, would be carried either ashore or to sea, in either case escaping fossilization.

*A single instance should be excepted in which a fish, fossilized in the usual position, shows the caudal fin turned on its side.

†If this evidence be admitted the curious coccostean "fishes" of the Cleveland shale are also to be interpreted as lacking a swim-bladder. There is, I believe, but little ground for associating them with ganoids and lung fishes.

THE LOESS OF NATCHEZ, MISS.

By B. SHIMEK, Iowa City, Iowa.

PLATES X-XVI.

The loess of Natchez, Miss., and of the lower Mississippi valley, besides presenting a specially interesting field to the student, is classic ground, for here loess was first recognized in America by Sir Charles Lyell, who visited the region in 1846.

It has received much attention since that time, and has been reported upon successively by Wales*, Hilgard†, Chamberlin and Salisbury,‡ McGee,§ and Mabry,|| while its fossils have received some attention from Binney.¶

While it was at first regarded as distinct from the loess of the upper Mississippi drainage, it is indistinguishable from it in its physical characters,—especially from that which may be designated as Missouri river loess. There are certain peculiarities of the fossil fauna of the southern deposit which have already received some notice, but for the most part the references to them are vague and unsatisfactory, and do not sufficiently set forth their significance.

It was the writer's good fortune to visit Natchez (and also Vicksburg) in May and June, 1898. The visit was made chiefly for the purpose of studying the fossils of the loess and comparing them with the modern molluscan fauna now inhabiting the same region. As a result of this investigation more than 4600 fossil shells were secured, and some additions were made to the collections of modern molluscs from Mississippi and adjacent states made by the writer in previous years. The season, however, was very unfavorable for collecting living snails because of the long-protracted drought which caused them to hide away. This probably accounts for the comparatively small number (less than 900 specimens) of modern snails in the Natchez collection, of which more than one-half belong to a species (*Succinea groscenorii*) not represented in the local loess.

In all more than fifty exposures of loess were studied at Natchez, and several were examined at Vicksburg, where but

*Wales. First Mississippi report, 1854.

†Hilgard, E. W.—Agriculture and Geology of Mississippi, 1860.

‡Chamberlin, T. C. and Salisbury, R. D.—Sixth An. Rep. U. S. Geol. Survey., 1885.

§McGee, W. J.—Twelfth An. Rep. U. S. Geol. Survey., 1891.

||Mabry, T. O.—Journal of Geology, vol. VI, 1898.

¶Binney, W. G.—A Manual of American Land Shells, Appendix IX, 1885, etc.

one day was spent: The location of the principal exposures which received attention at Natchez is shown in the accompanying map.* The topography of the region is striking. The Mississippi has cut away the deposits on the east side until bluffs exceeding 200 feet in height face the river. In addition to this smaller streams have washed out deep gullies whose almost perpendicular sides rise from 50 to nearly 200 feet. In all the region which was investigated the highest points are uniformly close to the river, while the outlying region is much lower. This is well illustrated by the ridge on which Natchez stands. Reference to the map will show that the altitudes† in the western part of Natchez, near the bluffs, vary from 180 to 210 feet above low water in the river, but gradually drop to 75 feet on the plain into which St. Catherine's creek has cut its channel. This plateau, or broad ridge, is seamed and cut by the "breaks," "gulfs" and "guts" described by McGee,‡ which offer abundant opportunities for the study of numerous exposures, most of which reach far below the loess, and permit easy penetration into its undisturbed mass. The loess is uni-

*

Explanation of the map.

The figures in parentheses represent altitudes above low water mark (O) in the Mississippi river.

The bridge across St. Catherine's creek on the Liberty road, not shown on the map, is 75 feet above low water.

The remaining numbers mark the exposures, the numbers corresponding to those employed in the table of fossils.

The following exposures lie beyond the limits of the map:

No. 26, along Liberty road, east of St. Catherine's creek. Its altitude is about 105 feet above low water.

No. 30, made by a deep gulley in a mass of loess lying considerably lower than the bluffs, some distance north of No. 29. Like no. 28, it contains broken fossils which suggest possibilities of land-slides from the bluff above.

No. 31, north of no. 30, forming a high bluff facing the river, and very similar to no. 29.

No. 32, an exposure high up on a hill north of the National cemetery, at an altitude of about 210 feet above low water.

No. 33, an exposure about half-way down the bluff along the road leading to the river bottom north of the National cemetery.

No. 34, along the road just north of no. 35, and somewhat higher.

†These were obtained in part from barometric readings, and in part from more exact data furnished by Captain Babbitt of Natchez.

‡McGee, W. J., l. c., p. 434. See also Plate X.





formly the uppermost deposit, forming the immediate subsoil, on the ridge on which Natchez is located. Underlying it in most of the exposures is the Yellow or Brown loam, which closely resembles loess, but is not fossiliferous and is usually of a deeper red color, though sometimes practically indistinguishable from it. Hilgard* described the Yellow or Brown loam as overlying the loess. Later McGee† in giving the order of the members of the Columbia formation, places the Brown or Yellow loam above the loess, but adds: "The order of the first two members might be reversed with equal propriety in the southern portion of the embayment; for the loess is but a phase of the loam, and is frequently underlain as well as overlain by loamy deposits." Again (p. 393), referring to the succession of strata at Natchez, he places the loess at the surface and the brown loam below it,—which accords with the writer's observations in that vicinity. Still later Mabry‡ discussing the relation of the brown loam to the loess, said: "It would appear that, if my observations be accurate, the Brown loam and the loess of this region are not only homotaxial but synchronous as well."

Whatsoever may be the exact relation existing between these two deposits elsewhere, at Natchez there appears no trace of the brown loam above the loess so far as the writer was able to determine.

The thickness of the loess at Natchez has been variously reported. Lyell§ gave it as sixty feet, but he probably included the Brown loam; Hilgard|| reported its average thickness as between twenty-five and thirty-five feet; McGee¶ states it as ten to fifty feet; while Capt. C. W. Babbit, of Natchez, an experienced surveyor and civil engineer who has had much to do with excavations, assured the writer that it nowhere exceeded twenty-five feet in thickness. The writer's own measurements showed a maximum thickness of about thirty feet, though in the exposures numbered 29 and 31 on the map, it seemed to be much more, but accurate measurements could not be made. It is probable that the front portion of

*Hilgard, E. W., l. c., pp. 194-195.

†McGee, W. J., l. c., p. 392.

‡Mabry, T. O., l. c., p. 295.

§Prin. of Geology, vol. I, p. 460.

||P. 313, l. c.

¶P. 397, l. c.

the bluff had slipped in part and thus exaggerated the apparent thickness of the loess. Such slipping was well illustrated opposite exposure No. 12 at r. A mass of loess about 25 feet high, 15 feet wide and 165 feet long slipped vertically about two feet. Subsequent erosion of the face of the bluff at one end of the mass made it appear as though the mass extended from the original upper surface to the new lower surface,—a distance of about 27 feet. The underlying Orange sands, which are easily washed out, always make such faults possible, and consequently care must be exercised in making measurements on the exposed faces of bluffs.

The material of the deposit possesses typical loess characters. It is a fine yellow or slightly bluish clay, showing a tendency toward vertical cleavage, containing lime nodules and iron tubules, occurring on higher grounds, and abundantly fossiliferous. Its hypsometric distribution is also like that of the northern loess, for it mantles the hills, and varies but little in depth. This is well illustrated in Plate XI. In many respects it is strikingly like the loess along the Missouri river, being somewhat coarser and containing more lime, and consequently eroding less readily, than the loess of the upper Mississippi valley in Iowa and Illinois. But for the undermining of the underlying sands and gravels it would long resist the action of air and water. Along the N. O. & N. W. R. R., in the cut near the depot, (exposure 1 on the map), the very steep sides still retained the marks of pick and shovel at the time that the photograph reproduced in Plate XII was taken, though the excavation had been made about seven years before.

This similarity of the Natchez loess and that of the Missouri river bluffs in all excepting fossils suggests the probable source of much, if not all, of the material which composes it.

The fossils are the most interesting feature of the southern loess. Here, as elsewhere, the characteristic fauna is moluscan, but differs in many respects from that of the northern loess. Notwithstanding the fact that the fossils formed the special object of the writer's investigations, there were found among them no species which are aquatic, or in any sense even "semi-aquatic." Not even those forms which belong to the fauna of the small pond and shallow stream, and which sometimes occur in northern loess, were found here. Singular

ly, too, such species are quite absent from the modern fauna of the uplands in and about Natchez, for there are no springs, or ponds, or swampy areas in which such snails as *Physa*, *Limnaea*, etc., might thrive. It is true that aquatic species have been reported from this loess, but in all cases the reports are either indefinite, or refer to that which may not be loess.

As early as 1846 Lyell* noted a deposit at Natchez resembling loess and with "land, fluviatile and lacustrine shells of species still inhabiting the same country," but he did not designate them by name. Later, discussing the loess of Natchez in the London Times† he said that the deposit "contains abundance of fresh water and land shells, of which I myself obtained more than 20 species. . . . They belong to the genera *Helix*, *Helicina*, *Pupa* and *Succinea*, accompanied or rather replaced in a few places where the loam passes into shell-marl by *Lymnea*, *Planorbis*, *Physa*, *Cyclas*. . . . All species are identical with Testacea, now inhabiting the same part of the U. S." The species of *Helix*, *Helicina*, *Pupa* and *Succinea* are, however, in no sense aquatic, and it will be observed that the deposit from which the shells of the species belonging to the aquatic genera *Limnaea*, *Planorbis*, *Physa* and *Cyclas* (*Sphaerium* or *Pisidium*) were obtained is very doubtfully loess,—certainly not typical loess. Finally, in the Principles of Geology‡ Lyell says that this loess is "full of land-shells such as *Helix* and *Pupa*, together with the amphibious genus *Succinea*, all of species now living in the same country. At a few points in the lower part of this formation, I observed shells of living species of *Lymnea*, *Planorbis* and *Cyclas*,—genera which inhabit ponds. . . . The only fossils of a truly fluviatile character which have been met with anywhere in this loess are the remains of three fish discovered lately (March 19, 1866) by Colonel Green. They were found in the great platform of loess, two miles north of Vicksburg, and only four feet below the surface, at the height of 200 feet above highwater mark." The genus *Succinea* cannot be properly designated as amphibious. It consists of two very distinct groups of species, to only one of which, represented by the species *retusa* (*ovalis*), the term may be applied, and this

*Athenæum. Sep., 1846

†Dec. 8, 1846; reprinted in the Am. Jour. Sci. and Arts, 2nd series, vol. III, pp. 267-269, 1847.

‡Vol. I, p. 460, 1872.

one is not represented in the southern loess, and but very sparingly in that of the north. The common and characteristic species of the loess, not only at Natchez but in all the Mississippi valley, belong to the other section of the genus, of which *S. obliqua*, *S. grosvenorii* and *S. avara* are members, and all of these are upland species, or at least are commonly found on higher grounds,—and none of them are in the remotest sense aquatic or “semi-aquatic.” Viewed in the light of the quotation from the *London Times*, the deposit in which the pond snails were obtained can scarcely be referred to typical loess. The occurrence of the fish-bones is unique and throws no light on the prevailing loess conditions. Such limited quantities of material might have been carried to the highlands by birds or mammals, and subsequently buried deeply by dust.

McGee also says* that this loess “yields . . . shells of land snails sometimes associated (particularly at lower levels) with shells of water snails and other fluviatile mollusca.” No names are given, and the reference is probably based on Lyell’s statements. The same is probably true of the following reference:† “The loess is unusually rich in shells of land and swamp mollusca, together with a few aquatic species.”

Altogether the evidence of the occurrence of aquatic shells in the southern loess is very unsatisfactory. They certainly cannot be very abundant or widespread if among the 4600 specimens collected by the writer there is not one aquatic shell.

The occurrence of vertebrate remains in the southern loess is quite as doubtful. Lyell’s fishes have already been discussed. He had previously stated‡ that the shells already noted are “associated with bones of mastodon, elephant, tapir, and other megatherioid mammals.” Again, in the *Principles of Geology*§ he says: “As to the mammalia of which some bones have been found in the lowest part of the loess and in clay at its base, they are many of them extinct species. Among them are *Mastodon giganteus*, a species of *Megalonyx*, a *Mylotherium*, *Bison latifrons*, *Equus americanus*, *Felis atrox*, ... species of deer, two of bear and other quadrupeds, some extinct and others still living.”

*P. 393, l. c.

†P. 399, l. c.

‡Athenaeum, 1846.

§P. 461.

Wailes, in his first report, said:* "The following list of the mammals found in a solid blue clay, said to belong to this formation ("bluff," or loess), was furnished by Dr. Leidy:

<i>Felis atrox</i> , Leidy.	<i>Tapirus haysii</i> , Leidy.
<i>Ursus americanus</i> , foss.	<i>Equus americanus</i> , Leidy.
<i>Ursus amplidens</i> , Leidy.	<i>Bootherium cavifrons</i> , Leidy.
<i>Megalonyx jeffersonii</i> , Harlan.	<i>Cervus virginianus</i> , foss.
<i>Megalonyx dissimilis</i> , Leidy.	<i>Bison latifrons</i> , Leidy.
<i>Mylodon harlani</i> , Owen.	<i>Elephas primigenius</i> .
<i>Ereptodon priscus</i> , Leidy.	<i>Mastodon giganteus</i> .
<i>Tapirus americanus</i> , foss.	

Of these the last named is by far the most common....

"They are found about twenty feet below the surface, and the bones of other animals are associated with them."

A comparison of the two citations shows that the two lists are practically the same. The "solid blue clay" is in all probability not loess. The writer found no trace of these mammals in the loess at Natchez, though molluscan remains were abundant. But even if it proves that these mammals are found in true loess the problem herein discussed will not be affected, as they are terrestrial and, if in true loess, only in its lowest, or oldest, parts.

The characteristic fossils of the loess at Natchez, as elsewhere, are land snails. They are found in all fossiliferous loess-exposures north and south, and the writer at least, has failed to find any other fossils in undoubted loess in the south.

These fossils have already received some attention. Lyell's references to them have already been quoted. Wailes† gives the first specific list of species from the southern loess, identified wholly or in part by Conrad. They were obtained from the "bluff formation," or loess, of Mississippi, and most of them were probably from Natchez. They are:

<i>Helix albolabris</i>	<i>Helix perspectiva</i>
" <i>alternata</i>	" <i>profunda</i>
" <i>concava</i>	" <i>thyroides</i>
" <i>elevata</i>	" <i>tridentata</i>
" <i>fraterna</i>	

To this list Hilgard adds‡ *Helix monodon* and "a large *Achatina* found in Wilkinson county." Of these species

*See also Hilgard, l. c., p. 196.

†P. 283, l. c., also quoted in Hilgard, l. c., p. 196.

‡P. 195, l. c.

H. alternata and *H. perspectiva* are now placed in the genus *Pyramidula*, *H. concava* in the genus *Circinaria* and the remaining species of *Helix* in the genus *Polygyra*, *H. fraterna* being a variety of *P. monodon*. The "*Achatina*" is probably *Bulinulus*, and not from the loess. At least it has not been found in the loess along the Mississippi, though it is a characteristic species of the southern modern terrestrial molluscan fauna, and its occurrence as a fossil would not be surprising.

W. G. Binney frequently refers to loess or "post-pliocene" fossils in his works on modern terrestrial molluscs, and many of them are unquestionably from the bluffs of the lower Mississippi,—some of them being specifically reported from Natchez. In 1865* he reported two species of terrestrial molluscs from the "post-pliocene of the Mississippi valley" (for the most part undoubtedly loess), one of them being a southern species which is known from the Natchez loess. In 1869† he reported 19 terrestrial species from the same indefinite source. Of these 15 species were found by the present author at Natchez. They are the following:

<i>Hyalina</i> (now <i>Gastrodonta</i>)	<i>ligera</i>
<i>Macrocyclus</i> (now <i>Circinaria</i>)	<i>concava</i>
<i>Helix</i> (now <i>Pyramidula</i>)	<i>alternata</i>
" "	" <i>perspectiva</i>
<i>Strobila</i> (now <i>Strobilops</i>)	<i>labyrinthica</i>
<i>Helix</i> (now <i>Polygyra</i>)	<i>stenotrema</i>
" "	" <i>hirsuta</i>
" "	" <i>monodon</i>
" "	" <i>palliata</i>
" "	" <i>inflecta</i>
" "	" <i>albolabris</i>
" "	" <i>elevata</i>
" "	" <i>exoleta</i>
" "	" <i>profunda</i>
<i>Succinea obliqua</i> (now <i>ovalis</i> Say)	

Of the remaining four species one, *Helix* (now *Pyramidula*) *solitaria* does not belong to the southern fauna.‡

The remaining three species, *Helix* (now *Polygyra*) *thyroides*, *H. clausa*, and *Helix* (now *Gastrodonta*) *gularis*, are

*Smith. Miscell. Coll., no. 144, Sep., 1865.

† In Binney and Bland, —Land and F. W. Shells of N. Am.—Smith. Miscell. Coll., p. 194; Feb., 1869.

‡The writer has reason to believe, from private correspondence with Mr. Binney, that the shells reported under this name are *Pyramidula strigosa loensis*, a species belonging to the northern loess.

found in the modern southern fauna and their occurrence in the southern loess would not be surprising. Mr. Binney later specifically reported *P. clausa* from the "post-pliocene" of Natchez. In 1870, in the 2nd edition of Gould,* he similarly reported nine of the foregoing species, of which the present author failed to find but one at Natchez, namely *H. thyroides*. The variety *bucculenta* of this species does however occur at Natchez, and may have been the form to which reference was made. In 1878 Binney again similarly reported† the nineteen species already mentioned, and added *Zonites* (now *Omphalina*) *fuliginosa* and *Z.* (now *Gastrodonta*) *intertexta*, and specifically reported *Triodopsis* (now *Polygyra*) *obstricta* from "Natchez Bluff." These three additional species are southern. The specimen reported as *Zonites fuliginosus* is really *Omphalina kopnodes*, a species not rare in the loess of Natchez. *Gastrodonta intertexta* (Binn.) Pils. is not known from Natchez, but is found in the South. *Polygyra obstricta* is frequent in the Natchez loess. The same species were again reported in the text of his Manual of Am. Land Shells in 1885, but in addition to this that work contains a catalogue of the Binney collection donated to the U. S. National Museum‡ in which twelve species are reported from the "post-pliocene" of Natchez. They are the following:

<i>Macrocyclis</i> (now <i>Circinaria</i>)	<i>concaea</i>	4	specimens.
<i>Zonites</i> (now <i>Omphalina</i>)	<i>fuliginosus</i>	1	"
<i>Stenotrema</i> (now <i>Polygyra</i>)	<i>stenotremum</i>	2	"
"	"	2	"
"	"	4	"
<i>Triodopsis</i>	"	1	"
"	"	4	"
<i>Mesodon</i>	"	4	"
"	"	2	"
"	"	3	"
"	"	4	"
"	"	3	"

It was the writer's privilege to examine this collection in 1899, and he found that not only is the single specimen marked *Zonites fuliginosus* (no. 38806 of the collection) doubtfully from the "post-pliocene," but it is *Omphalina kopnodes*. Mr.

*Invertebrata of Mass., A. A. Gould, Edited by W. G. Binney, 2nd ed. 1870.

†The Terr. Air-Breathing Moll. of the U. S., vol. V.

‡See Appendix IX. pp. 471-489

Charles T. Simpson of the U. S. National Museum, to whom the question was later referred, states in a private letter that "this *Omphalina* is more solid than any *capnodes*, *friabilis* or *fuliginosa* I have seen but agrees most nearly with *capnodes*."* *Omphalina fuliginosa* is therefore omitted from the final list of Natchez loess fossils, as Mr. Binney's specimen is the only one reported from the loess. Its occurrence as a fossil, however, would not be strange as the species is common in the south, and occurs living on the bluffs at Natchez.

With the exception of *Polygyra clausa* all the species in Binney's list were found by the writer in the loess at Natchez, and 27 species and recognized varieties were added to that locality list, and two further species, *Polygyra fraudulenta* and *P. palliata*, were added at Vicksburg. Of these 29 species *Polygyra thyroides bucculenta*, *P. fraudulenta*, *Pyramidula alternata costata*, *Gastrodonta multidentata*, *Vitrea placentula*, *Punctum pygmaeum*, *Vertigo tridentata* and *Carychium exile* are here reported for the first time from undoubted loess, while *Polygyra palliata* and *Gastrodonta ligera* have heretofore appeared only in Binney's rather indefinite "post-pliocene" lists, without locality. Inasmuch as several of the fossil species are now also living in the vicinity of the loess exposures great care was exercised in collecting the fossils. Some specimens of every species in the list of fossils, with the exception of *Pupoides marginatus*, were obtained by digging in undoubted undisturbed loess. Plate XII shows one of these excavations at the right. In some cases additional specimens were collected in the loess talus, but their characteristic heavy chalky appearance, the presence of like shells in the undisturbed loess above the talus, and the absence of modern shells of the same species from the immediate vicinity of the particular exposures from which the shells were obtained, leave no doubt that they too are true loess fossils. The single specimen of *Pupoides* was collected in such talus, but its appearance is that of a loess fossil. Moreover, the species occurs in the loess elsewhere. It is therefore here included as a fossil.

In some cases the fossil shells were imbedded in large limestone nodules, and occasionally small nodules form partial casts of the shells. Some are shown in Plate XIII. Fossils were

*It is a striking fact that the shell quite uniformly appears heavier in loess fossils than in modern specimens of the same species.

collected from twenty-six exposures at Natchez, and from a cut along the Vicksburg and Meridian R. R. at Vicksburg, and the several locality sets were kept separate. The accompanying table of species gives the number of fossils of each species collected from each exposure,* thus giving a comprehensive view of the distribution and relative abundance of the several species. In making comparisons, however, it must be borne in mind that the several exposures are not of equal extent, nor are they even relatively equally fossiliferous. Eight of the larger exposures† proved to be non-fossiliferous. Exposures 1, 2, 3 and 4 are really in the same large cut, and exposures 5 and 6 are likewise opposite sides of one cut, while on the other hand No. 11 is a more or less broken series of exposures around the great "gulf" shown on the map just south of Natchez. It is especially fossiliferous on the south and east sides of the "gulf."

Numbers 1, 2, 3, 6, 7, 8, 9, 11 and 17 are the most extensive of the fossiliferous exposures, and relatively the richest. They are all located in the southwestern part of the area under discussion.

Exposures 19 to 26 inclusive, along the Liberty road, are mostly smaller cuts and "guts" along a wagon road, and are not to be compared with the large exposures mentioned.

The number of modern shells of each species found at Natchez is given in the last two columns of the table. In order that some conception of the peculiarity of local distribution of modern shells may be gained, the collections made on the bluffs toward the north are listed separately from those which were taken on the hills southwest of Natchez. The grouping of the fossils of the species in the loess is singularly like that of modern shells on the surface.

The modern shells were all collected on higher slopes. No collections were made on the Mississippi bottom lands.

Polygyra clausa should be added to the list of Natchez fossils on the authority of Binney.

It will be noticed that all the species of the accompanying table are terrestrial, and all are now found living either on the

*The Natchez exposures are numbered, the number at the top of each column corresponding to the number on the map. No fossils were found in the exposures not included in the table.

†Compare map and table of fossils.



gularis (Say) Try., and *Succinea grosvenorii* Lea. The first three species are restricted to the southern states. *Succinea grosvenorii* is now locally very common northward to South Dakota, especially in the country bordering the Missouri. Its center of distribution is far north of Natchez, and its southern extension may be of comparatively recent date. The species is very common in the northern loess along the Missouri river.

The Natchez fossils bear out the writer's oft-repeated statement that the loess fossils of any given region are practically identical with the modern molluscan fauna of the same region.* Indeed, they furnish the most convincing proof of this interesting and important fact which has yet been presented. The most characteristic and widely distributed species of the northern loess, such as *Helicina occulta*, *Succinea grosvenorii*, *Pyramidula striatella*, *Vallonia gracilicosta*, *Polygyra multilineata* and *Pupa muscorum*, are wholly absent from the southern loess, as, with the exception of *S. grosvenorii*, they are from the modern fauna of that region, while *Succinea avara*, so common in the north, and so frequent there as a fossil, is very rare in both the fossil and modern faunas of Natchez.

More than one-half the species in the Natchez list of fossils have also been found in the northern loess, while the following eighteen species are thus far known only from the loess of the south:

<i>Helicina orbiculata</i>	<i>Omphalina kopnodes</i>
<i>Polygyra fraudulenta</i>	<i>Vitrea placentula</i>
<i>inflecta</i> .	<i>Gastrodonta ligera</i>
<i>albolabris</i>	<i>multidentata</i>
<i>exolcta</i>	<i>Pyramidula alternata costata</i>
<i>palliat</i>	<i>Punctum pygmaeum</i>
<i>obstricta</i>	<i>Strobilops labyrinthica</i> (probably)†
<i>elevata</i>	
<i>thyroides bucculenta</i>	
<i>stenotrema</i>	

Polygyra albolabris and *Punctum pygmaeum* are the only species in this list which, judging from present distribution,

*Bull. Nat. Hist. St. Univ. Iowa, vol. I, p. 213.—1890.
 Proc. Ia. Acad. Sci., vol. III, p. 84.—1896.
 Proc. Ia. Acad. Sci., vol. V, p. 41.—1898.
 Proc. Ia. Acad. Sci., vol. VI, p. 99.—1899.
 Jour. Geol., vol. VII, p. 132.—1899.

†The *S. labyrinthica* of the earlier reports on northern loess fossils is probably all *S. virgo*.

are likely to be found in the northern loess. The remaining twenty-four of the species listed in the table of fossils have all been found more or less abundantly in northern loess.

Several additional points of interest are presented by some of the Natchez fossils. Only two of the shells of *Polygyra thyroides bucculenta* have the parietal tooth. The remaining edentate specimens somewhat simulate *P. clausa*, but they are less elevated, and not so heavy nor so coarsely striate as the shells of that species. The parietal tooth is easily broken off in the fossils of this and other species, and in identifying fossil species too much importance must not be attached to its absence.

The fossil *Polygyra hirsuta* is the small form, approaching *maxillatum*, which is the common form in the south. *Polygyra monodon* is the form usually named *leai*, and *P. monodon fraterna* is the form generally known as typical *monodon*.*

The modern shells and the two fossils are of the "*leai*" type, but have a smaller umbilicus than the northern form. Most of the fossils are of the larger *fraterna* type. It was at first thought by the writer that the fossil shells of *Gastrodonta multidentata* might be *G. lamellidens* Pilsbry†, but a careful examination of the teeth shows that the fossils are without doubt *G. multidentata*. Modern *G. multidentata* is reported from southeastern Tennessee by Ferriss.‡

Fossil *Pyramidula alternata* and var. *costata* are not always sharply distinguishable, but the specimens listed as *costata* all show more or less clearly the coarse ribs which characterize this southern variety.

Succinea ovalis Say is the species well known as *S. obliqua*.§ The snails' eggs could not be identified, but they are undoubtedly eggs of land snails. Two species were collected.

The Natchez loess is of special interest because it furnishes particularly weighty arguments against both the aqueous and glacial theories of the origin of the loess. That this loess is not of aqueous origin is shown by its fossils, which are terrestrial upland species, and by its distribution over a high ridge, higher than the surrounding country for many miles around.

*On authority of Pilsbry.—Proc. Acad. Nat. Sci. Phil. for 1900,—pp. 454-5.

See Nautilus, vol. XI, p. 134.

†Nautilus, vol. XIV, p. 58.—1900.

‡See The Mollusca of Chicago Area, Frank C. Baker.—Bull. Chicago Acad. Sci., no. III, pt. 2.

A body of water sufficient to cover this ridge would form an inland sea, with land on which the molluscs might develop so remote from present Natchez hill that it would have been necessary to transport them a great distance by water. That it is extremely improbable that the shells of the loess at any point have been transported any considerable distance by water has already been shown by the writer.* That those of Natchez have not been so carried seems to be established beyond a doubt by the following facts:

1. At Natchez several shells of *Helicina orbiculata* were found with the operculum lying within the aperture, a position which it could not occupy if the shell-bearing animal had been deposited in water, for it becomes detached immediately after decay has set in, and would be carried away. Modern upland dead specimens are frequently found with the operculum lying within the shell.

2. The extremely delicate shells of snails' eggs are preserved in the loess. They are so frail that they would scarcely stand transportation by water.

3. The larger perfect fossil snails uniformly have the spire of the shell empty, no clay having been carried into the shell beyond the body-whorl, as would have been the case in drifting and finally submersed shells.

4. The fact that the local fossil and modern faunas are very similar has already been emphasized, and further indicates that transportation of shells from a distance has not taken place.

5. There are no traces of beaches, shore-lines, etc., such as would be left by a large body of water such as this theory postulates, nor does the remarkable homogeneity of the deposit taken together with its distribution suggest the possibility of deposition in flooded streams.

That the Natchez loess was not deposited by glaciers or icebergs is, if possible, even more evident. Natchez lies far south of the limits of glaciation, hence floating icebergs only need to be considered. Icebergs, however, would require a great body of water to float them over Natchez hill, and the objections to this have already been considered. Moreover, the fossils of the Natchez loess are, as shown herein, in large part

*Proc. Ia. Acad. Sci., vol. V, pp. 40-41, 1898.

such species as inhabit the warmer parts of our country today, and there is nothing in the molluscan fauna of this loess which would suggest even the remotest possibility of a glacial climate.

It appears that the aeolian theory offers the best explanation of the origin of the loess not only of Natchez, but of all the Mississippi drainage. The writer's first paper in which a modified form of the aeolian theory was presented,* was based almost wholly on the study of fossils, and subsequent investigations, geological, paleontological and botanical (for the loess presents an interesting problem to the plant ecologist, and the influence of plants on the formation of the deposit seems to be great), have only served to emphasize in the main the conclusions therein presented, though perhaps modifying them in some details. The chief purpose of the subsequent papers† was rather the demonstration of the impracticability and impossibility of the generally accepted theories which postulated aquatic and glacial conditions.

While it is not purposed here to enter upon a detailed discussion of the positive evidence in favor of the aeolian theory, this being reserved for a more extended paper on that subject, certain considerations which have a direct bearing upon loess in general, and upon that of the southern Mississippi valley in particular, are here presented together with the writer's conception of the origin of the loess.

To make the formation of such a deposit as the loess possible it is necessary to have: 1) A source of supply of material at hand; 2) an agency capable of transporting the material; and 3) a lodging place upon which it may be safely anchored. Where any of these conditions fail there can be no deposition of material, and no loess will be formed; where these conditions are best developed there the deposit will be thickest. It has long ago been observed that the loess is best developed along our larger river-courses, and it is there that these conditions are all most likely to be presented. A more detailed reference to these conditions may be of interest:

1. *The source of supply.*—It is quite generally conceded that the finely comminuted particles which make up the loess origin-

*A Theory of the Loess.—Proc. Ia. Acad. Sci., vol. III, pp. 82-89, 1896.
†Proc. Ia. Acad. Sci., vol. V, pp. 32-45, 1898; vol. VI, pp. 98-113, 1899; vol. VII, pp. 47-59, 1900.
Journal of Geology, vol. VII, Mch., 1899.
Bull. Lab. Nat. Hist. St. Univ. of Iowa, vol. V, pp. 195-212, May, 1901.

ated primarily in the drift. In the north it was loosened and sifted out from the coarser material by rain, by wind, by burrowing worms, insects, mammals, etc., and by scratching birds, and to some extent by growing plants, while its volume was increased by the chemical decomposition and disintegration of the coarser materials thus exposed.*

Some of this material was washed into the streams, and some of it was (and is) blown about by the winds. In the southern Mississippi valley, where there is no glacial drift and yet an abundance of loess, the material of the loess was probably all brought down by the great river, and chiefly by its Missouri branch. During the summer months our streams reach their lowest levels. Great bars of sand and mud are thereby exposed to the dessicating influence of sun and wind. During the summer, too, strong winds sweep along their valleys and gather up the fine material so exposed.†

With it also mingled more or less of the finer material gathered by the winds directly from higher grounds, and perhaps with calcareous particles from fluviatile shells where present in the streams, but the main supply in the south and perhaps in large part elsewhere where loess was formed, was obtained from the bars of the stream.

2. *The agency.*—The objections to water and ice as agencies of transportation have already been briefly stated. Wind does carry large quantities of material, and in the loess regions winds are strong and frequent during the summer season when the soils are loose and easily eroded. Moreover, the general southerly course of the larger streams in the Mississippi valley, along which most of the loess is deposited, favors the concentration of the prevailing southerly winds in the troughs of the valleys, through which they crowd with increased force, and dislodge the fine particles of detritus brought down by the streams and exposed in bars. In the north drifting snows, especially in the Missouri river region, also gather up and carry great quantities of dust.

3.—*The anchorage.*—The material so gathered up must be deposited in a place from which it cannot easily be dislodged by

*That finer material is thus removed and the coarse material so concentrated near the surface has already been observed. See *Proc. Ia. Acad. Sci.*, vol. IV, p. 70, 1897; etc.

†For discussion of the probable amount of this material see *Jour. Geol.*, vol. VII, p. 135.—1899, or *Proc. Ia. Acad. Sci.*, vol. VI, pp. 109 and 110.—1899.

erosion if it is to add to the sum-total of the deposit. It is a well known fact that plants check or prevent erosion. The more luxuriant the vegetation the less erosion is produced by rainstorms. This is especially true of forests. The most violent rainstorms will scarcely disturb the finest leaf-mould even on very steep slopes in the woods, while they wash out great quantities of material in more open country. Vegetation, and especially forest vegetation, is best developed along the streams.

It will thus be seen, that these three favorable conditions, while not restricted to streams, are yet best developed adjacent to them, and could accomplish more than would be possible at more remote points. That this is true appears also from the evidence of the snail fauna. The loess is thickest, and also most fossiliferous, in close proximity to streams, and near them, too, modern land-snails are most abundant. The fact that fossils are more abundant near streams than they are in more remote regions does not indicate a difference in the origin of the respective deposits,* but merely further shows that terrestrial conditions along streams, even on high grounds favor the development of snails. The reason that snails are not found fossil in the loess remote from streams is that when living they do not, to any extent, inhabit such places.

Time.—The element of time is also to be taken into account. It might seem that, if loess was deposited most abundantly where vegetation was comparatively vigorous, there ought to be an abundance of plant remains in the deposit. The rate of deposition, however, must have been so slow that all organic matter would have disintegrated long before it could have been covered and sealed in the deposit. Organic remains can be thus preserved only when overwhelmed, especially in wet places, and their absence would rather militate against the aqueous theory. If the rate of net deposition, after deducting loss by erosion, already estimated by the writer,† namely, 1 mm. per year, be accepted, it is evident that a stick or log, or even a leaf, would decay long before it could be entombed in the deposit. At that rate a log one foot in diameter, for example, would require more than three hundred years for burial. The shells of molluscs do

*See Hershey's article in *Am. Geol.*, vol. XXV, pp. 369-374.—1900.

†*Jour. Geol.*, vol. VII, p. 135, and *Proc. Ia. Acad. Sci.*, vol. VI, pp. 109 and 110.

not similarly disintegrate, and are preserved as fossils, partly because of their composition and texture which better enable them to resist exposure, and partly because all of these terrestrial snails are more or less inclined to burrow, or at least conceal themselves in the lowest strata of leaf-mould, etc., and their shells are soon covered up.* In many respects the borders of the drift-sheets in the north, especially where morrainic, presented conditions similar to those now existing along the larger streams. This question, however, does not concern the loess of Natchez and Vicksburg, and will be discussed at another time.

Whatsoever may be the difference of opinion concerning the soundness of the foregoing conclusions, the loess of Natchez materially reinforces the evidence against the possibility of the aqueous origin of the loess, and practically renders the theory of glacial origin untenable.

The writer desires here to express his obligations to President Fish of the Illinois Central R. R. and Prof. Samuel Calvin of the Iowa Geological Survey, whose kindly courtesy made the preparation and publication of this paper possible.

EXPLANATION OF PLATES.

PLATE X.

A SMALL "GULF" SOUTHEAST FROM EXPOSURE NO. 6. THE STRATIFIED ORANGE SANDS SHOW IN THE BLUFF. THE LOESS IS NOT VERY DISTINCT. THE BOTTOMS OF MOST OF THE BROADER GULFS ARE QUITE FLAT, AND CONTAIN NO PERMANENT STREAMS.

PLATE XI.

LOOKING SOUTHEAST FROM A POINT EAST OF EXPOSURE NO. 7. THE UPPER VERTICAL PORTION IS LOESS. BELOW IT IS AN IRREGULAR, RATHER NARROW LAYER OF DARK BROWN LOAM, AND BELOW THAT THE ORANGE SANDS AND GRAVELS ARE COVERED LARGELY BY A LOOSE TALUS.

*To collect some of our smaller species of modern snails which are also represented in the loess, in autumn or during dry summers, it is necessary to pull up the roots of smaller plants among which many of the snails are concealed.



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LOOKING SOUTHEAST FROM A POINT EAST OF EXPOSURE NO. 7. THE UPPER VERTICAL PORTION IS LOESS. BELOW IT IS AN IRREGULAR, RATHER NARROW LAYER OF DARK BROWN LOAM, AND BELOW THAT THE ORANGE SANDS AND GRAVELS ARE COVERED LARGELY BY A LOOSE TALUS.

*To collect some of our smaller species of modern snails which are also represented in the loess, in autumn or during dry summers, it is necessary to pull up the roots of smaller plants among which many of the snails are concealed.



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not similarly disintegrate, and are preserved as fossils, partly because of their composition and texture which better enable them to resist exposure, and partly because all of these terrestrial snails are more or less inclined to burrow, or at least conceal themselves in the lowest strata of leaf-mould, etc., and their shells are soon covered up.* In many respects the borders of the drift-sheets in the north, especially where morrainic, presented conditions similar to those now existing along the larger streams. This question, however, does not concern the loess of Natchez and Vicksburg, and will be discussed at another time.

Whatsoever may be the difference of opinion concerning the soundness of the foregoing conclusions, the loess of Natchez materially reinforces the evidence against the possibility of the aqueous origin of the loess, and practically renders the theory of glacial origin untenable.

The writer desires here to express his obligations to President Fish of the Illinois Central R. R. and Prof. Samuel Calvin of the Iowa Geological Survey, whose kindly courtesies made the preparation and publication of this paper possible.

EXPLANATION OF PLATES.

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specimens figured by Weller* tho' not better than the *L. yandellianum* Hall from Spergen Hill, Ind., a species which is conspicuous perhaps because of its good preservation. Compared to this one, the specimens from Humboldt are ten diameters larger tho' of so nearly the same taper that inferior specimens might be taken for the same species in spite of size in view of the fact that some others which were first described from Spergen Hill fossils were based on minute or immature shells. Girty† and Keyes‡ also have figured specimens of *Loxonema* without names, but near enough geologically to deserve mention here.

The shell of *L. difficile* n. sp. is large, of 15 or less volutions, gradually expanding to a length of 12 cm. with apical angle of near 25°. Each volution is impressed by one half the preceding one measuring from the superior suture to the lower inner angle. Counting ten units in that distance, the surface is distinctly concave for two units, equally convex for the next two, strongly convex crossing the periphery for the fifth unit to the line of the inferior suture, thence gently convex below but rounding narrowly to the imperforate columella. The diameters measured vertically and transversely are nearly equal but obliquely the height and width are as 8 to 5. The suture is distinct. Surface smooth except for fine growth varices which run sigmoidally, the backward curve above the periphery being about half as deep as wide, the forward curve below it being equally deep tho' with longer radius. The shell thickness is rather uniform in the spire and the internal cavity changes gradually from subangular to oval.

Seven specimens were found at Humboldt and at Rutland, in the Kinderhook strata.

***Murchisonia* sp. indet.**

One specimen was found at Rutland, Ia. It is an entire shell rolled in a pisolith, and discovered in section by grinding. It is 18 mm. long with acute apex, and 12 volutions of which the last is six mm. across, measuring obliquely. A marked angulation lies below the middle and the suture is distinct. The columella is minutely perforate. The surface is not shown.

* Kinderhook Faunal Studies; *Trans. Acad.*, St. Louis, vol. ix, x, xi.

† *Monogr.* 32, U. S. G. S., pl. 66, f. 9.

‡ *Missouri Geol. Sur.*, vol. v, pl. 55, f. 2.



PLATE XII.

LOOKING WEST ALONG THE N. O. & N. W. R.R. FROM A POINT
NEAR ITS EASTERN TERMINUS. THE EXCAVATION TO
THE RIGHT IS EXPOSURE NO. 1. THE OVER-HEAD
BRIDGE IN THE BACK-GROUND IS ON
CANAL STREET.

PLATE XIII.

THE FIGURES ARE ALL NATURAL SIZE. NUMEROUS LARGE
NODULES WERE FOUND, BUT NONE CONTAINED A
GREATER NUMBER OF SHELLS THAN
THOSE FIGURED.

EXPLANATION OF PLATE XIV.

- Fig. 1. *Polygyra albolabris* (Say) Pils.
2. " *exoleta* (Binn.) Pils.
3. " *profunda* (Say) Pils.
4. " *elevata* (Say) Pils.
5. " *obstricta* (Say) Pils. The upper specimen has lost the
parietal tooth.
6. " *thyroides bucculenta* (Gld.) Pils. The upper specimen
without parietal tooth.
7. " *stenotrema* (Fer.) Pils.
8. " *monodon fraterna* (Say) Pils.
9. " *monodon* (Rack.) Pils.
10. " *hirsuta* (Say) Pils.
11. " *inflecta* (Say) Pils.
12. *Omphalina kopnodes* (Binn.) Pils.
13. *Pyramidula alternata* (Say) Pils.
14. " *alternata costata* (Lewis) Clapp.
15. *Circinaria concava* (Say) Pils.
16. *Succinea ovalis* Say.
17. *Gastrodonta ligera* (Say) Pils.
18. *Pyramidula perspectiva* (Say) Pils.
19. *Cochlicopa lubrica* (Müll.)
20. *Helicina orbiculata* Say.
21. *Vitrea indentata* (Say) Pils.

Two views of each species are given, front and lower surface, ex-
cepting in figs. 9 and 19, of each of which only one view is given, and
13 and 14 which show three views each. The figures are natural size.

PLATE XV.

VIEW OF NATCHEZ BLUFFS, LOOKING SOUTHWESTWARD. AT LOW
WATER THE WATER IN THE FOREGROUND RECEDES AND EX-
POSES EXTENSIVE MUD-BARS. EXPOSURE No. 26 IS JUST
VISIBLE NEAR THE TOP OF THE HILL ALONG THE ROAD
IN THE FOREGROUND. THE DEEP CUT IN THE PROJECT-
ING POINT OF THE BLUFF IN THE BACKGROUND IS
EXPOSURE ALONG THE N. O. & N. W. R. R. EXPOS-
URES 5, 6, 7 AND 8 ALSO SHOW INDISTINCTLY.

THE CARBONIFEROUS FORMATIONS OF HUMBOLDT, IOWA.

F. W. SARDESON, Minneapolis.

PLATE XVII.

During the past summer, the writer spent several days in Humboldt county, Iowa, and found an opportunity to become more nearly acquainted with that somewhat isolated geologic field, one which few geologists are known to have visited. White described it briefly long ago and MacBride has recently again described† it. Their accounts do not nearly exhaust the readily obtainable geologic information, especially of the Carboniferous formations, considerable additional being at once evident. Nor does the matter herein presented complete that which may be learned there. It is the purpose of this article to indicate some remaining fertile spots in that geologic field.

Humboldt county, it may be repeated here, lies in the prairie region of northern Iowa, midway between the Mississippi and Missouri rivers. It covers the confluence of the East and West Des Moines rivers, upon a glacial plain which slopes in general from northwest to southeast, somewhat more than 100 feet in 30 miles. MacBride says that "the highest elevation within its limits rises not more than 30 or 40 feet above the general level." The Des Moines rivers "occupy comparatively narrow channels, cut down from 20 to 70 feet below the level."

The geologic formations are nearly horizontal or dip in the same direction and in nearly the same degree as the plain. The exposed formations are accordingly few. The cliffs and wooded hills along the rivers are doubly attractive by reason of contrast to the broad face of cultivated prairie and they are also the prime source of geologic information. The approximate northern limit of coal measures and the limit here of natural exposures of stratified formations beneath the glacial drift, in extension toward Minnesota are scientifically worthy of special note. The peculiar method of draining the prairie land with its numerous shallow glacial basins, by means of natural and artificial sinks is economically of interest, and as

† *Iowa Geol. Sur.*, vol. ix, pp. 117-147, 1898.

tions which are seen outcropping at Humboldt and Rutland, lying flatly under the glacial boulder clay; that before the clay was put there by glaciers the surface of the county was upon those sandstone and limestone formations; then it is evident that the water at that time soaking through a soil reached the cracks which all limey rocks possess and the humic acids in the water may have crowded or eaten out some crevices into channels, some of which formed sinks finally at the surface. This is evident in the underground channels as seen opening on the cliff at Rutland, which when judged by the same method as one would the crossing of two wagon tracks to determine which is the older,—these channels are older than the rivers channel and older than the glacier's work of erosion and deposition. These underground channels also probably permeate the Kinderhook limestone throughout the area beneath the Drift, and drained at one time probably numerous sinks over the country, prior to the glacial changes.

Not only is it true that "the limestone which underlies the region now in question appears to be full of fissures, and as a result we have subterranean drainage," but evidently a system of preglacial large channels exists there. Evidently the two successive glaciers pushing from the north filled boulder clay over the sinks, though some of them have re-opened by gradually swallowing up a great quantity of clay. Where the Drift is thickest as north of the Bloody Run none have re-opened. The existing sinks now do not lie at the bottom of the surface glacial basins but anywhere seemingly that they happen to have been before, though probably some new ones are forming, by leakage from the sloughs as MacBride says.

In boring new sinks the conditions of the natural ones may be closely followed, *i. e.*, the well should enter the oölitic limestone and there strike open channels, or failing to do so, blasting in the well to shatter the rock facilitates the flow out of the drill hole to the channels. If such a well drains at all, each flood of water with its acids from the soil may be expected to corrode the limestone, making the drain more effective continually, in the manner of the natural sinks which are hardly choked. The failure of a well at Humboldt to serve as a sink in a quarry is due obviously to the low level

of its head; the great springs here are indeed nearly at the same level, and are probable outlets of the underground channels.

The conclusions "that a well deep enough to furnish an inexhaustible supply of water will also on the other hand, receive any amount of water that may be poured into it" and that "in any case, of course, the well must reach an aquifer or water bearing stratum" are in the main true but are not direct, I think, to the line of cause and effect. Those conditions may be met in the deeper drift covering by wells reaching only some gravelly layer in the drift and in such cases they may be good at first but later they may fail as in very wet seasons the gravel beds tend to overflow or backwater, they having no good outlet. Also the gravel beds not being of lime the well can not be expected to improve with age. It also floods into the aquifers which are used most by wells supplying drinking water. Again a well passing into the channel-bearing limestone in some places may reach air-filled cavities as good as water-filled ones.

To what great extent this system might be developed remains to be seen though in any case it must be limited to favorable conditions in the underground here, especially to those of the Kinderhook formation, the extent of which under the glacial clays needs to be systematically followed out. This may be done in course of time owing to economic advantages.

The system of drains into sinks obviates the otherwise necessary waste of land by open ditches, but more than that the attractive feature of it seems to me to lie in the amelioration of river floods. The water which is turned underground goes into reservoirs so large on the aggregate that flooding at the inlets probably affects very slightly and slowly the flow from the outlet springs. The rivers are relieved of just so much flood which they would receive from ditches and they are augmented thereby at low stages. Near the sinks the water for drinking may easily be taken from a higher or lower aquifer into which the water from sinks can penetrate only by thorough filtering.



Overlying this there was twenty feet of the so-called plains-marl. Below the bone layer there was a four-inch layer of a sandy conglomerate, which rested directly upon the Niobrara chalk, here forming a bluff to the north of the bone deposit. The bone bed when cleared off was about ten feet square, and contained the skeletons of five or six adult animals, and two or three younger ones, together with a foetal skeleton within the pelvis of one of the adult skeletons. The animals had evidently all perished together, during the winter. There was no possibility of the accidental intrusion of the arrow-head in the place where found, as the superincumbent material had all been removed ten feet back before exposing the skeleton. It must have been within the body of the animal at the time of death, or have been lying on the surface beneath its body."

The material covering the skeletons was the wide-spread upland marl, doubtless in part of wind origin. In the same material, and not far distant from the place where the bones were exhumed, I have obtained bones of *Elephas primigenius*, a species characteristic of the Equus Beds.

A brief notice of this discovery was published by me in Vol. II, Kansas University Geological Survey (1896) in a discussion of the Pleistocene fauna of Kansas.

DISCOVERY OF THE LARAMIE IN NEBRASKA.

By C. A. FISHER, Lincoln, Neb.

PLATE XVIII.

The geology of Nebraska presents broad structural features. The shales, clays, and partly cemented sands of the Cretaceous and Tertiary occupy the surface throughout a large part of the state, with the underlying Carboniferous limestone outcropping in the southeast corner. The stratigraphic relations are very uniform with few regional disturbances, bringing underlying formations to the surface. As a result of these conditions, few formations are represented in the state. Considering the limited number, the mere fact that the Laramie formation does occur in Nebraska, however small the area may be, seems worthy of mention.

Hitherto, the Cretaceous formation in Nebraska was thought to be represented by the Dakota, Benton, Niobrara, and Pierre, occurring in successive order from east to west in





the state. The Laramie was known to outcrop in eastern

EDITORIAL COMMENT.

WAS THE DEVELOPMENT THEORY INFLUENCED BY THE "VESTIGES OF THE NATURAL HISTORY OF CREATION."

Concluded.

Among the important factors of the modern theory of development, the following may be found in this treatise by Robert Chambers (?) The analogy of embryology and phylogeny are distinctly enunciated; the parallel and concomitant progress of parent and derived forms are pointed out; the inadmissibility of making horizontal comparisons of the various forms of different classes or sub-kingdoms at any given epoch, and on the other hand the necessity of admitting the "vertical" connexion of sequent species; the failure of the geological record and the consequent futility of the objection of missing links; the effect of changed conditions in giving permanency to altered forms of living things (including the arrest of development by withdrawal of part of the usual forces through which it is effected, illustrated—(p. 174)—by the experiment of Milne Edwards with tadpoles, sunk in the Seine in a perforated box, which grew into abnormally large tadpoles but did not change into frogs)—all these are stated as clearly as afterwards by Darwin, Huxley, Haeckel and many others.

He only missed the thought of the continually recurring accidental modifications becoming persistent through the survival of the fittest in the struggle for existence. But this is an explanation of the theory rather than the theory itself; an explanation too without which the theory might well be maintained. In this connection it is worthy of mention that the cause of this survival suggested by Darwin, and adopted by his school, viz.: natural selection, has never received a support equal to that accorded to the fact of evolution. Yet beyond a few casual and usually depreciating mentions by the great soldiers of the modern development theory this author has been entirely neglected.

P. F.

NOTE.—The foregoing should have been the closing part of "Editorial Comment" in the October number, having been omitted by mistake.—*Ed.*

WHAT CONSTITUTES A CLAY.

That kaolin is the basis of all clays is the commonly accepted opinion of most writers. The evidence upon which such an opinion is based is largely chemical and, it must be confessed, unsatisfactory—so unsatisfactory, in fact, that the present writer has ventured at times to doubt the accuracy of the statement altogether. That kaolin is a clay is unquestionable, but that all the materials possessing the plasticity of clays and their property of becoming indurated on drying, or baking, can be found to contain even non-essential portions of kaolin, has not yet been proven.

Even the question as to what kaolin itself may be is evidently problematic in the minds of many writers, a majority of whom will simply refer back to the time-worn textbook definition to the effect that kaolin is a hydrous silicate of aluminum corresponding to the formula $\text{Si}_2\text{O}_5\text{Al}_2\text{H}_4$, which is that of the mineral kaolinite—a mineral micaceous in structure, hexagonal or rhombic in outline, but monoclinic in its crystallographic properties.

As to the primary origin of kaolin, we are taught that it results from the breaking down of aluminous rocks, principally feldspars, through the ordinary atmospheric agencies comprised under the name of weathering, the processes consisting in the removal, wholly or in part, of the more soluble salts, as those of potash, soda, and lime, and the accumulation of the practically insoluble hydrous aluminum silicate as a residue. With many writers the name kaolin is applied to the residual materials, whether left in place by the decomposing agencies or separated from mechanically admixed impurities through the action of water.

Through becoming contaminated with various impurities, the kaolins, we are taught, pass over into the various types of clay, classified, according to their demonstrated fitness for any particular kind of work, as brick, tile, terra cotta, pipe, fireclays, etc., the last name being applied to clays which, composed mainly of aluminum silicates and relatively poor in the alkalies, lime, or iron, are highly refractory and suitable for fire brick.

The cause of the plasticity of clays as a whole is little understood, and it is doubtful if any of the attempted solutions

of the past twenty-five years would be found to hold, were the subject gone over again with the methods of research available today. By some plasticity is looked upon as largely due to the chemical properties of the clay; and undoubtedly the amount of combined water has an important influence. With others the matters of size, shape, and relative abundance of the constituent particles and their conduct towards absorbed water are primary factors. It must, however, be evident to any one who peruses the literature at all carefully that there still remains much to be learned, and that much that is written consists in merely a reiteration of statements made many years ago, before the perfection of the microscope as an instrument for the study of rocks, and while the science of chemistry was yet in its infancy.

In spite of much good work that has recently been done, I can but think that the clays have not as yet received the attention they deserve from a strictly scientific standpoint. They are complex bodies, with complex and striking peculiarities, and there is ample field for further investigation.

The immediate cause of the above is the appearance in the *Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie*, XV Beilage-Band, 2d Heft, of an article comprising pages 231-393, by H. Rösler, entitled *Beiträge zur Kenntniss einiger Kaolinlagerstätten*. The paper represents a large amount of work and is worthy of careful perusal and consideration, even though one should be inclined to question some of the conclusions.

This writer reserves the name kaolin to the raw product obtained by washing the natural kaolinized granite or quartz porphyry. The apparent varying composition of kaolin, as shown by different analysts, he regards as due to admixed impurities. The presence of a free aluminous hydroxide, as claimed by Kasai, and also the slight deficiency in silica commonly shown, he looks upon as due to a lack of accuracy in analyses.

He finds no sharp line of separation between kaolin and fireclays; in this most writers will agree with him. The plasticity of kaolin and the fireclays he regards as due principally to the flattened form of the constituents, their softness, and their fineness. The hard-burning of many of the plastic clays he regards as due largely to the small size

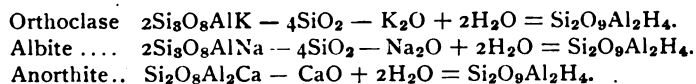
of their particles, other things being equal. The fact that the water-transported clays or kaolins are more plastic than the residual is regarded as due to the abrasion they have suffered during the process of transportation. As bearing upon the effect of the shape of the particles upon plasticity, he instances the fact that clays kneaded in a "Schlepp" mill, where the motion is a crushing and dragging one and such as to give rise to flattened particles, are more plastic than those kneaded, for the same length of time, in "Trommel" mills, where the resultant particles are angular and of irregular form. This, too, he thinks will explain the fact that an unplastic clay cannot be rendered plastic through artificial grinding, whereby the kaolin particles become broken into angular bits, which never have the same degree of plasticity as the naturally rounded and waterworn particles. (Is not this a trifle contradictory?)

The tendency shown by the finely ground kaolins to crack in the process of baking, he seems to regard as due to the explosive action of the steam generated by the heat, the compactness of the clay rendering its gradual escape impossible. He notes that the plagioclase feldspar undergoes kaolinization much more readily than does orthoclase, and that the latter is itself more readily attacked than microcline.

The transformation of the three most important feldspars into kaolin he shows as follows:

	SiO ₂	Al ₂ O ₃	K ₂ O	H ₂ O	%
1. Orthoclase	64.86	18.29	16.85	.....	100.00
Lost	43.24	.....	16.85	.....	60.09
Taken up . . . . .	.....	.....	.....	6.45	6.45
Kaolinite	21.62	18.29	.....	6.45	46.36
	SiO ₂	Al ₂ O ₃	Na ₂ O	H ₂ O	%
2. Albite	68.81	19.40	11.79	.....	100.00
Lost	45.87	.....	11.79	.....	57.66
Taken up . . . . .	.....	.....	.....	6.85	6.85
Kaolinite	22.94	19.40	.....	6.85	49.19
	SiO ₂	Al ₂ O ₃	CaO	H ₂ O	%
3. Anorthite	43.30	36.63	20.07	.....	100.00
Lost . . . . .	.....	.....	20.07	.....	20.07
Taken up . . . . .	.....	.....	.....	12.92	12.92
Kaolinite	43.30	36.63	.....	12.92	92.85

From this it appears that, in the case of orthoclase and albite, two-thirds of the silica and all the alkalies are removed. In all, over half of the feldspathic constituents are lost during the transition, while, in the anorthite, only the lime is carried away. The proportional loss and gain he shows as follows:



In other words, two molecules of albite or orthoclase are necessary for the formation of one molecule of kaolin, while, in the case of anorthite, one molecule is sufficient for one molecule of kaolin.

The formation of kaolin or steinmark, through the decomposition of other minerals, as scapolite, leucite, nephelin, sodalite, hauyn, analcite, topaz, etc., while in some cases regarded as chemically possible, he thinks has not yet been proven.

A mineralogical study of a large number of kaolins showed the usual accessory minerals, some of which are original and others secondary, the original minerals being, naturally, the more refractory constituents, usually existing only in microscopic proportions, which have escaped the chemical decomposition. These are mainly apatite, biotite, monazite, xenotime, mica, rutile, spene, zircon, etc. Good crystalline forms of kaolinite are rarely met with in the kaolins, the material occurring in small irregular shreds, often so small as to be determined only with great difficulty. With the kaolin he finds associated nontronite (chloropal).

To the statements generally accepted by American authorities, at least, and put forward originally, I believe, by Kasai, to the effect that kaolin, as the depth or distance beneath the surface increases, will be found to pass gradually into the fresh rock from which it was derived, he takes exception, and states that such an occurrence has never been actually proven, although there are abundant instances of its passing into the fresh, undecomposed rock laterally. He would consider kaolin as due never to atmospheric action; that weathering and kaolinization are two independent processes; and that the kaolin itself is the product of what he designates as a post-volcanic pneumatolytic and pneumatohydatogenic process.

In other words, that kaolinization is comparable with serpentinization and similar changes such as are commonly grouped under the head of hydro-metamorphism. This is, perhaps, the most striking of the conclusions arrived at in the paper under consideration.

Unfortunately, the author does not give us satisfactory evidence of the correctness of many of his assertions, and one can but feel that many of his statements are based upon the literature rather than actual experiment and observation. Moreover, the list of quoted authorities, however large, is not quite satisfactory to the American reader. Thus, Dr. Ries, of Cornell, who is undoubtedly our best authority, is wholly ignored. It may be well, on this account, to call attention to the fact that Dr. Ries, in a paper read at the Detroit meeting of the American Ceramic Society in 1900, discusses the possible origin of kaolin through fluoric vapors, instancing the work of Mr. Collins (*Min. Mag.*, 1887), and stating it to be his opinion that the kaolins of Cornwall were undoubtedly of deepseated origin and possibly, also, those of Zettlitz in Bohemia. He affirmed, however, that there were as yet no known similar occurrences in America, all of the beds thus far exploited being due to surface weathering. To this view he still holds, as does also the present writer.

More observations are, of course, necessary to establish this non-occurrence of deepseated kaolins beyond question, but it will be only necessary to call attention to the fact that, almost without exception, our residual kaolins, of sufficient extent to be of commercial importance, occur south of the glaciated areas, to throw a very substantial doubt upon the advisability of accepting Mr. Rösler's conclusions in their entirety.

G. P. M.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

United States Geological Survey, Twenty-first Annual Report to the Secretary of the Interior, 1899-1900. CHARLES D. WALCOTT, Director. Part IV. Hydrography. F. H. NEWELL, Chief of Division. Pages 768, with 156 plates, and 329 figures in the text. Washington, 1901.

The first paper in this volume is F. H. Newell's "Report of Progress of Stream Measurements for the Calendar Year 1899," in

488 pages, with 57 plates and 271 figures. It discusses the measurements of the flow of many streams throughout the United States, partly obtained from the engineer officers of the Army, and from individuals and corporations, but mostly from the field work of the hydrographers of the Geological Survey. The data are presented in diagrammatic form, as well as by statistical tables. Surveys of reservoir sites have been continued, and also various investigations relating to the utilization of water for irrigation, power, and other industrial purposes. The largest consideration is directed toward the reclamation of the arid lands in the western half of the United States, of which the greater part, about 56 per cent., remains vacant. It is estimated that 78,000,000 acres, comprising a seventh part of the vacant lands, are capable of irrigation sufficient for agriculture.

Mr. N. H. Darton, in the second paper, gives a "Preliminary Description of the Geology and Water Resources of the Southern Half of the Black Hills and Adjoining Regions in South Dakota and Wyoming," pages 489-599, with plates 58-112, and figures 272-299. This report describes an area of about 5,500 square miles, in respect to its structural and economic geology, water supply for irrigation and stock-raising, timber, climate, and the history of its topographic development.

The entire Cretaceous period is found to be represented in this district, with an aggregate thickness of at least 5,000 feet of sediments. The sandstone series forming the lower part, until recently regarded as a single formation, named the Dakota sandstone, is found, within the last few years, to comprise not only a formation carrying an Upper Cretaceous flora, to which the term Dakota is now restricted, but also extensive Lower Cretaceous deposits. In their descending order, these are named the Fuson formation, of sandstone, shale, and mudstone; the Minnewaste limestone; and the Lakota formation, mainly sandstone. All the Cretaceous formations are uplifted by the Black Hills dome, often to steep angles. The principal epoch of the uplift was probably Early Eocene; and the larger topographical outlines, as truncation of the dome and valley erosion, were far developed before the White River epoch of the Oligocene period.

In the third and last paper of the volume, Mr. Willard D. Johnson treats of "The High Plains and their Utilization," pages 601-741, with plates 113-156, and figures 300-329. A lengthy review of an advance copy of this paper was published in the *AMERICAN GEOLOGIST* for last January.

W. U.

Glacial Formations and Drainage Features of the Erie and Ohio Basins. By FRANK LEVERETT. (U. S. Geological Survey Monographs, Vol. XLI., Washington, 1902, 802pp., 20 pl., 8 fig. Price \$1.75.)

This great volume is a worthy successor to the same author's Monograph XXXVIII, "The Illinois Glacial Lobe," published in 1899. Alone it would establish the reputation of any geologist. And it displays not only the author's ability and superior skill in the diagnosis

overflow to the Illinois-Mississippi. The enlarged lake Maumee extended from Fort Wayne northeastward to the ice front 150 miles (covering some 50 miles of the western end of the present lake Erie), with two arms along the north and south sides of the glacier lobe. The southern beaches extend to Girard, Pa., and the northern into Lapeer county, Mich. Its total area was larger than that of the present Erie. The present altitude of the upper beach at the Fort Wayne outlet is about 775 feet. When the Huron-Erie ice lobe receded still farther northward and downward on the "thumb" of Michigan the Maumee waters found another yet lower outlet, at Ubley (also discovered by Taylor), and the initial outlet at Fort Wayne was finally abandoned. This lake, called Whittlesey by Taylor, was 30 feet lower than Maumee but also contributed its waters to lake Chicago. The shoreline of Whittlesey, called the Belmore beach, named by N. H. Winchell in 1872 (the Ridgeway of Spencer), extends eastward to Marilla, N. Y., 15 miles east of Buffalo. This lake covered the greater part of the Maumee valley, all the area of the present lakes Erie and St Clair, with a large territory in Canada. Its total surface was more than twice that of the present Erie.

With yet farther retreat of the ice front in Michigan the Whittlesey waters found lower escape than by the Ubley outlet, and with a fall of 50 or 60 feet they became confluent with those of lake Saginaw. The expanded waters are known as lake Warren, using a name of Spencer. Being lower, the Warren waters were more constricted in the Erie basin than the Whittlesey, but the total area was far greater. They covered a large area in the Saginaw valley, including all of Saginaw bay and the lower end of lake Huron, a considerable area in Canada, including the western end of the present Ontario; and an irregular belt through the "Finger" lakes region of New York. The entire surface was perhaps three times that of Erie, and averaged 200 feet higher. The beaches of lake Warren are complex. The upper persistent ridge is known as the "Arkona" and a lower one the "Forest," with an interval of 10-20 feet. In central New York the Forest level alone is thought to be represented.

As these ancient beaches were all laid down in horizontality, but are not now level, they are of value especially as a means of measuring the amount of deformation which the Laurentian region has suffered in post-glacial time.

The freshest feature of the book, and the most useful to teachers and students, is the series of beautiful maps. These show the main features of the Pleistocene geology in the best style of modern cartography. Another valuable feature is the complete bibliography.

The slight errors which the reviewer has noted are merely sufficient to emphasize the accuracy of the work, which is noteworthy, considering the vast area covered and the complexity of the phenomena.

H. L. F.

Asiatic Russia. By GEORGE FREDERICK WRIGHT. Two volumes, pp. xxii, xii, 637, with 10 maps, and many illustrations from photographs. New York: McClure, Phillips & Co., 1902. Price, \$7.50, net.

This very comprehensive work is based largely on the observations of the author during a tour in the year 1900, with his son, Frederick Bennett Wright, through China, Siberia, Turkestan, and Russia. It is extended, however, outside the range of their travel, to treat quite fully of all the vast area owned by Russia in Asia, as to the physical geography, the history of the Russian conquest and colonization, the diverse native tribes, the present social, economic, and political conditions, and the archaeology, geology, climate, flora, and fauna. The entire area comprises six and a half million square miles, or nearly twice that of the United States and Alaska.

Professor Wright, after considering the history, resources, and present conditions of the country and people, gives the following optimistic view for the future of this great empire. "Looking at Asiatic Russia as a whole and with its present limits, it is therefore easily within the bounds of possibility, and even of probability, to expect that before the close of the twentieth century it will have a population of 100,000,000, provided a stable government can be maintained and peace be permitted to reign, so that man shall be unhindered in his efforts to perfect his conquests over the powers of nature. With this vision before him it is not surprising that the Tsar should long for peace, nor that he should be almost alone in this desire; for, more than any other country in the world, Russia is in position to obtain the main objects of national ambition through the next one hundred years by turning attention to the development of the internal resources of her own empire. Apparently there are operating within her body politic all the forces which, if wisely guided, will secure the highest objects of national ambition, namely, a steady increase of population, accompanied by a corresponding increase in the material supplies necessary for the comfort of the people, and for that association with one another and contact with the outer world which is necessary to foster the highest social and intellectual progress."

One of the leading motives for this extensive travel across Asia was to study the Quaternary geology, with the expectation that extensive mountainous and plateau regions in the interior of the continent would be found covered with glacial deposits. Though the high mountain ranges now bear conspicuous glaciers and snowfields, no evidences of a general ice-sheet covering large districts were found. But lake Baikal, 1,561 feet above the sea, and 4,186 feet deep, inhabited by seals almost identical with a species of the Arctic Ocean, indicates that great epeirogenic movements have taken place there in very late geologic times. From the amount of sediments brought into this lake by its largest tributary, the Selenga river, the time since the lake began to exist is estimated as no more than 50,000 or perhaps even 30,000 years. The general changes of land altitude and contour implied by the formation of lake Baikal seem thus to have been a part of the vast epeirogenic

changes which preceded and attended the Ice age. While they brought greater elevation for northern and western Europe and North America, their effect for much of Asia was probably a contemporaneous subsidence.

The distribution of the loess in large districts of China seems chiefly attributable to wind action, as was first shown by Richthofen and Pumpelly; but in Turkestan, on the northwestern side of the great continental plateau, Wright found the wind hypothesis untenable. He says: "Evidences accumulated that the land had lately been depressed to such an extent that the water of the ocean reached the base of the bordering mountains, rising to a height, certainly, of about 3,000 feet; for, at this level, south and southwest of Lake Balkash, we found the loess spread out in such an extensive terrace that the wind would be entirely incompetent to produce the results."

Marine submergence, thought by the author to have affected a very extensive tract of northwestern Asia, would cause the unsubmerged eastern part of Siberia to have a moister and warmer climate, giving pasturage for herds of the mammoth and woolly rhinoceros far to the north, even beyond the Arctic circle. With re-elevation of the land and the disappearance of the vast inland sea, the present severe extremes of climate would ensue, causing these species to become extinct.

An excellent chapter on the climate of the Russian empire is contributed by Mr. F. B. Wright, summarizing the results of weather observations during many years at 564 stations, of which 225 are in Asiatic Russia, as published two years ago in a most elaborate climatological atlas by the Nicholas Physical Observatory at St. Petersburg. As results of the climate, Siberia consists of three zones, the most northern being the treeless Arctic tundra; the next southward is a wide belt of forest; and still farther south are the grassy and flowery steppes, similar to our prairies and plains between the Mississippi river and the Rocky mountains.

W. V.

Les Roches Alcalines caracterisant la Province Petrographique d'Ampasindava, par A. LACROIX. (Nouvelles Archives du Muséum d'Histoire Naturelle, 4th Series, Vol. I. 4to, 152 pages, ten plates. Paris, 1902.)

Only the first hundred and fifty pages (premier fascicule) of this important contribution to petrography have as yet appeared; but some features of interest may be noted briefly—The work is divided into three chapters; the first is devoted to a description of the eruptive rocks of Nosy Komba, Madagascar, and their contact phenomena; the second gives the results of study of the rocks of the bay of Ampasindava and incidentally rocks from a few other localities in Madagascar. The third chapter is devoted to the deductions drawn from these studies and the theoretical discussions of a general interest to which they lead. The last chapter and part of the second have not yet appeared.

It follows clearly from the descriptions published that the northwest part of Madagascar is a province characterized by a great variety of those highly sodic rocks which are generally so rare, and which have

constituted so rich a field of petrographic inquiry within the last few years.

Contact phenomena occupy a place of prominence in the study—For instance, Lacroix describes (p. 58 *et seq.*) in detail all the steps in the metamorphism of an argillaceous quartzite (argile siliceuse) to a rock containing none of the original clastic minerals, and having a chemical composition corresponding to that of a possible igneous rock belonging to the family of the metamorphosing eruptive.

It is interesting to note that while the author does not anywhere distinctly state his views upon the question of differentiation, he seems to accept neither the extreme view of certain French petrographers who reject the theory *in toto*, nor the other extreme exemplified by certain German and American writers who would seemingly make of the theory a panacea for all the troubles of the student of petrogeny. Lacroix's position is perhaps partially revealed by the useful distinction he draws between varying facies (*faïces de variation*) of an eruptive magma and a true petrographic series. By the former he signifies the diverse petrographic types resulting from the heterogeneity of the rocks produced by the solidification of a given magma when they have no geologic individuality (as of dikes, sheets, etc.,) distinct from that of the main magma. If, however, these diverse petrographic types play a geologic rôle distinct from that of the normal rock, they together constitute a petrographic series. He is careful to add that these distinctions are independent of all theoretical explanations of the cause which has produced the rocks in question.

The conclusion of this publication will be eagerly awaited by all those interested in the advancement of petrography. A. N. W.

The Clays and Clay Industries of Wisconsin. By ERNEST ROBERTSON BUCKLEY. Bulletin No. 7, Part I (Economic Series, No. 4), Wisconsin Geological and Natural History Survey, E. A. BIRGE, Director. Pages 304, with 55 plates. Madison, Wis., 1901.

This report describes the clay deposits of Wisconsin, its 190 brick and drain tile factories, their methods of manufacture, and the economic conditions relating to the marketing of their products. The state has unlimited quantities of clay suitable for common building brick, terra cotta, fire proofing, drain tile, and earthenware. It is believed that other clay beds of less extent may be utilized for ornamental building brick, paving brick and vitrified wares, and a fair quality of fire brick. Very plastic white kaolin occurs at numerous localities in Dunn and St. Croix counties, which is found to be well adapted for the manufacture of the highest grades of porcelain. It is largely used now, but almost exclusively for mixing with wood-pulp in paper-making.

The extensive and thick clay formations adjoining lakes Superior and Michigan, which are regarded by the author as chiefly or largely of lacustrine or estuarine deposition, seem to the reviewer to be more properly classed, for the greater part, as boulder clay or till, deposited directly from the ice-sheet, without transportation by water, and only

slightly modified near the surface by the glacial lakes then held by the ice barriers at heights much above the present lakes. w. u.

Washington Geological Survey, Vol. 1, Annual Report for 1901; in six parts. HENRY LANDES, State Geologist, Olympia, Wash., Gwin Hicks, State Printer, 1902.

The state geological survey of the state of Washington (such is the official title) was established in 1901 by an act of the legislature and the sum of \$5,000 annually appropriated for the purpose of carrying out the provisions of the act. Professor Henry Landes of the University of Washington was chosen state geologist. Professor Solon Shedd, W. S. Thyng, and D. A. Lyon were appointed geologists, and Chas. E. Gaches, George W. Evans, Louis Pohle, and Lewis L. Ryan field assistants for 1901.

The first report which appears with creditable promptness and in good form from the state printer consists of the following papers: Part i. Creation of a state geological survey, and an outline of the geology of Washington, by Henry Landes. This latter is a brief account of existing knowledge of the geological provinces of the state and is accompanied by a process reproduction of a model of the surface and a preliminary geological map in black-line. Part ii is a report on the metalliferous resources of Washington, except iron, which presents a useful summary of the existing mines and ore-bodies in sight. Part iii deals with the non-metalliferous resources, except coal, including the building and ornamental stones, the soils and road-metals, with a discussion of the conditions in which petroleum is to be sought in western Washington. Part iv deals with the iron ores and coal deposits of the state. Part v deals with the water resources of the state. Part vi is a bibliography of the literature referring to the geology of the state.

The purpose of the organizers of the survey in giving accent to the economic aspects of the geology of the state has been fully carried out and the state geologist and his associates are to be complimented on the large amount of information which they have gathered in this annual report. Reports of this character cannot but prove a good investment for the state in making better known its natural stores of wealth and in enlisting capital and guiding an intelligent development of the commonwealth.

J. B. W.

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CORRESPONDENCE.

SKETCH OF DR. FRENZEL. In my mail of a few days ago I found the following letter from Dr. Beck of the Bergakademie of Freiberg Saxony.

" * "To my sorrow I must send you sad news from Saxon Freiberg. Our old and loved D. Phil. Frenzel died on the 29th of August of a cancerous tumor of the stomach. (*Kresbartige Magenverhärtung*). He was confined to his bed only eight days though he was weakened for a longer period. A few days before his death he became chief officer of the smelting office laboratory." * * "he left his family, a widow and two daughters, in comfortable circumstances."

This sad news of the death of one of the greatest of all mineralogists is particularly so to the writer who made his acquaintance in Freiberg in the early summer of 1866—36 years ago.

He was recommended to me as the special protégé of the great Breithaupt who in that year delivered his last course of lectures at the Bergakademie. I was attracted to the delicate, intelligent looking Inländer and soon a warm friendship grew up between us which only death has dissolved. Frenzel was the son of a Freiberg miner who lived and supported a family, as so many others have done and are doing, on twenty to twenty-five cents a day. His early experiences were of the extremest poverty; but when he was old enough his father sent August to the excellent Bergschule which the Saxon government under Von Beust had established to educate the children of the miners.

Showing unusual ability and docility he rapidly made himself a favorite, and easily won for himself a scholarship in the Bergakademie itself. At a very early period in his course he attracted the attention of the great mineralogist, Breithaupt, who called on him frequently for assistance in arranging new collections of minerals, and determining their species. Following his illustrious master he soon achieved phenomenal success in this direction even equalling his preceptor in the latter's opinion. But the way was hard, the father died and he must contribute to the support of his mother whom he tenderly loved.

August was unfit for the hard work of a miner. His skin was at this time sallow, and his face cadaverous; a Chinese-like intimation of a desultory beard, and a very thin and unhealthy moustache adorned a head set upon narrow shoulders and a flat chest. His hands were cold to the touch and he suffered frequently from headaches and other bodily ailments. Yet when the exigencies of his favorite science of mineralogy required it he would tramp over hill and dale with tireless energy and industry, leaving far in the rear those vastly more robust than he. At this period, when we were both students, he an Inländer and I an Ausländer at Freiberg, I knew him to determine correctly three well crystallized minerals behind his back with eyes bandaged, by the sense of touch alone. When his course was completed and his final examinations had been brilliantly passed, he was offered a subordinate post in the smelting laboratory, at a very small salary; and accepted ruefully because he had never cared for chemistry, while devoted to mineralogy. In spite of this however, he brought a true scientific mind, and a sense of high honor to the task before him.

He applied himself with the same diligence to metallurgical chemistry from a sense of duty, that he had consecrated to mineralogy from pure love of that science, and after some set-backs such as the loss of parts of his right digits through an explosion, (immediately following which accident, he learned to write admirably with the left hand), he attained a high standing among his colleagues. He was commended, if my memory serve me, for his report on the extent of damage to vegetation through the volatile products of the smelting works of the Mulda. He even succeeded in discovering what he took to be a new element and

isolating a small portion of its oxide. Owing to certain stringent rules of the German official scientific research offices whereby all the discoveries of a subordinate inure to his superior, Frenzel sent the present writer several grams of this isolated new element and the latter offered it at a meeting of the Chemical Section of the A. A. A. S. in Phila., 1884, asking that a committee be named by the president of the section to investigate the material and report on its elementary character. The offer was not accepted and the material was returned to its discoverer.

In 1886 science was startled by the announcement that Prof. Winkler of the Freiberg Mining Academy had accomplished for Germany what de Boisbaudran eleven years before had effected for France, the discovery of a new element; and following the example of his French colleague, he named it after his country—"*Germanium*" as the former had bestowed the name of "*Gallium*" on his newly found simple body. Whether or not this was the material found by Frenzel and communicated to me under so many safeguards, I do not know, but the coincidence is a curious one.

In spite of the handicap of his straitened circumstances Frenzel had already secured a valuable collection of minerals by purchase, exchange, and exploration before the end of 1870. This was increased and finally sold for quite a large sum, when another collection was begun and at last also disposed of. With his professional duties and cares and the correspondence and labor incident to the prosecution of his studies in his beloved mineralogy, one would have thought his days sufficiently full; but quite unexpectedly he developed a taste for zoology in the department of ornithology, and more specially in the order of *Psittaci* (parrots), and contributed several interesting papers beautifully illustrated with colored plates of love birds, to the zoological journals of Germany.

While Prof. Credner was chief geologist of the geological survey of Saxony, Frenzel issued his mineralogical dictionary of Saxony.

His name will be found here and there in Dana's and other standard mineralogies but not to the extent that is due his profound knowledge of structural, determinative, and chemical mineralogy, and had he been able to devote his time to these branches he would have probably become pre-eminent in them.

He had a gentle, affectionate disposition and a high sense of honor. For many years he made me the confidant of his most secret trials, and aspirations; and called upon me to share his joy at his triumphs. I have now a small silver medal which he won as a prize at the Bergschule. It is about as large as an old Saxon thaler and has engraved upon it simply "*Dem Fleisse*." This he insisted upon giving me when I had exceeded his anticipations in mastering the difficulties in crystallography in which he was instructing me. It is the conscientious, thorough, high toned, industrious men of his type which have made his Fatherland great in science.

May we in this country have many like him.

PERSIFER FRASER.

PERSONAL AND SCIENTIFIC NEWS.

MR. P. S. SMITH, M. A., has been appointed Assistant in Geology at Harvard University.

DR. J. P. IDINGS, of Chicago University, has been elected a foreign member of the Scientific Society of Christiania.

MR. E. C. ECKEL, of the New York survey, has been appointed to a position on the United States Geological Survey.

DR. A. R. C. SOLWYN for many years director of the Canadian Geological Survey, died Oct. 19, at his home in Vancouver, B. C., at the age of 78 years.

MR. R. G. McCONNELL, of the Canadian Geological Survey has spent the past season on the Canadian Yukon river, and is elaborating at Ottawa his notes and maps preparatory to his official report.

DR. R. A. DALY, geologist of the Canadian Commission, in locating the Canadian international boundary, recently returned to Ottawa, having spent the season along the boundary line east from the Okanagan river.

PROF. W. H. HOLMES, of the United States National Museum, was appointed by the secretary of the Smithsonian Institute, S. P. Langley, to be director of the Bureau of Ethnology. Prof. Holmes is one of the foremost ethnologists in the United States.

COLUMBIA UNIVERSITY.—New courses have recently been established in paleontology, viz.: Phylogeny of some group of invertebrates, involving the principles and methods of the Hyatt school; Invertebrate faunas of geologic horizons of North America, and a course in stratigraphy over a wide area directed to some single horizon, based on the foregoing course. The last will involve original research, with field work. The department has opened with a largely increased list of students.

DR. C. H. GORDON, SUPERINTENDENT OF THE CITY SCHOOLS of Lincoln, Nebraska, has been appointed instructor in geology and geography in the University of Nebraska. Dr. Gordon retains his position at the head of the city schools and will, for the present, carry one course in petrology, and during the spring semester one in geography, the latter designed especially for teachers or those having teaching in view. In addition to this work he will also, during the spring semester, repeat his course of lectures on school supervision and management given last year.

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[STUDIES FROM THE DEPARTMENT OF GEOLOGY,
UNIVERSITY OF NEBRASKA.]

NEW BRYOZOA FROM THE COAL MEASURES OF
NEBRASKA.*

By G. E. CONDRA, PH. D., Lincoln, Neb.

PLATES XVIII-XXV.

I. *Introduction.*

In the summer of 1896, at the suggestion of professor E. H. Barbour, the writer began a study of the fossil Bryozoa of the state. Since that date an abundance of material, representing over fifty species, has been collected, classified and described. This paper is only a part of a complete unpublished report in which both new and old species are described. Professor Barbour, Miss Carrie A. Barbour and Messrs. W. H. H. Moore, and E. C. Woodruff have assisted in the collecting. The illustrations were drawn by the writer, Mr. E. O. Ulrich and Mrs. G. E. Condra.

The writer is indebted to Messrs. E. O. Ulrich and R. S. Bassler for valuable assistance. Specimens sent to Mr. Ulrich for verification were returned with helpful notes. My especial thanks and gratitude are due professor Barbour whose kind and stimulating assistance has made this publication possible.

II. *Descriptions of species.*

***Fistulipora carbonaria* var. *nebrascensis* n. var.**

Pl. XVIII. Figs. 1, 2.

Zoarium large, massive; form irregular. A specimen collected at Louisville is fifteen by eleven by four and one-half centimeters in size,

* Read before the Nebraska Academy of Science, January 25, 1902.

smooth, wider than the zooecial apertures; thickened interspaces or small areas without apertures occur on the surface of the zoarium placed about 2 mm. apart. Zooecia quite vertical in the axial region and then bend slowly outward to the surface where they are not yet direct; walls thin in the immature region, thickened in the periphery; by vertical sections, narrow cortical and wide axial regions are shown. Tubes in the axial region, subcircular in section; walls 0.02 mm. thick. Owing to the thickened walls in the outer portions, the zooecial cavities decrease slightly in size near the apertures. Acanthopores quite numerous, not long, small and large, generally small, forming in sections, irregular circles about the zooecia, ten to fifteen in a circle; they do not in any way form divisional lines in the zooecial walls; a few acanthopores, 0.06 mm. in diameter, occur at the angles of the cells; small acanthopores 0.02 to 0.04 mm. in diameter. Tabulae scarce, absent in most zooecia. Mesopores few and small.

On account of the even cylindrical surface, few zooecia, and wide interspaces, this species is not apt to be confused with any of the associated species of *Rhombopora*. The interspacial areas, 1 to 2 mm. apart, when present, will also serve in its identification. On account of the few large acanthopores resembling those of *R. lepidodendroides* Meek, the specimens may be confused with that species. Other characters enumerated will amply serve for distinction. It is clearly distinct from all described species of *Batostomella*. Few specimens have been collected. One was sent to E. O. Ulrich who pronounced it new and a member of the genus *Batostomella*. The name is suggested by the even surface. Type specimens in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; South Bend, and Bennett, Nebraska.

***Stenopora heteropora* n. sp.**

Pl. XX. Figs. 1, 2.

Zoarium massive; surface with clusters of elevated apertures larger than the average; clusters 1.5 mm. across, 4 or 5 mm. apart. Apertures polygonal or rhomboidal, more or less in series about the clusters, 0.24 to 0.4 mm. across, average 0.26 to 0.3 mm., fourteen or fifteen in 5mm. Interspaces thin, 0.05 to 0.06 mm. wide. Zooecia about 3 mm. long, at first horizontal, and then with a quick curve, they pass direct to the surface; tubes polygonal, average diameter 0.27 mm., walls thin, usually not more than 0.02 mm. thick; near the surface they increase in thickness equal to that of the interspaces. Diaphragms thin, 5 to 8 in each tube, about 0.26 mm. apart in the straight portion of each tube. Acanthopores few, of medium size, located at the cell angles. The line of division between the adjacent zooecia is quite plain. The writer knows of no species of the genus more closely related to *Anisotrypa*.

The nearest related species is *S. rudis* Ulrich from which this differs mainly in zoarial form. The zoarium of that species consists of

hollow, irregular branches, while this species is massive. The walls, in section, resemble those of *S. cestriensis* Ulrich, but show smaller acanthopores and plainer divisional lines between the adjacent zooecia. The main points of specific importance are to be found in the varying sizes of the zooecial apertures and in the form of the zoarium. Type specimens in the museum of the University of Nebraska, Lincoln, Nebr.

Position and locality: Coal Measures, South Bend, Nebraska.

***Stenopora distans* n. sp.**

Pl. XX Figs. 3-5.

Zoarium an expanded crust, consisting of a single layer of zooecia, supported by a wrinkled epitheca; thickness 2 to 3 mm., width variable, average about 3 mm.; surface spinulose when not worn, with low monticules, or smooth. Apertures subcircular, not in regular lines, unequal in size, 0.25 mm. in diameter, fifteen or sixteen in 5 mm. Interspaces thick, with rounded surface, unequal in width, sometimes 0.15 mm. or more wide. Zooecia 2 to 3 mm. long, quite straight throughout the entire length; walls quite thick throughout the length of each tube, not plainly moniliform; zooecial tubes subcircular in section, of unequal diameters, varying from 0.16 to 0.28 mm. Large acanthopores occur at some of the cell angles; acanthopores 0.1 to 0.12 mm. in diameter, of regular form, circular in section, slightly more than half as numerous as the zooecia; small and less regular acanthopores, 0.03 to 0.05 mm. in diameter, occur in the walls between the large acanthopores; their number varies from about 10 to 15 surrounding each zoecium. Diaphragms thin, three to seven in each tube, irregularly disposed. Mesopores small, usually not more than 0.07 mm. in diameter, irregular in section, one-third to one-half as numerous as the zooecia.

To a limited extent, this species resembles *S. spinulosa* Rogers, in having similar though less numerous large acanthopores which are not disposed as they are in that species. The wide interspaces and the varying sizes of the zooecia serve as the main specific characters. The diaphragms are also of use in separating it from related species. Type specimens in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; Louisville, Nebraska.

***Stenopora* (?) *polyspinosa* n. sp. (Provisional.)**

Pl. XX. Figs. 6-10.

Zoarium ramose consisting of subcylindrical branches with diameters of 4 or 5 mm. Bifurcations far apart, with small angles. Surface smooth, except for numerous small and a few large acanthopores which project on the interspaces as low, blunt spines; the former give the surface a papillaceous appearance. Zooecial apertures subcircular, not arranged in series, 0.25 to 0.3 mm. in diameter, thirteen in five mm. Interspaces average 0.07 or 0.08 mm. wide. The zooecia ascend from the vertical axis of the branch, curve, and then pass in nearly a straight line to the cortical portion, where the walls thicken quickly,

and then continue direct to the surface. Walls, in the immature portion, very thin, 0.02 mm. thick; not moniliform; in the cortical portion they are evenly thickened and finely laminated. The small acanthopores are 0.04 to 0.07 mm. in diameter and more numerous than in other species collected in the state; they form in sections one complete series about each zooecium, with twelve to twenty in a series; at places, two or more incomplete rows are observed. A few large acanthopores occur at the angles of some of the zooecia. The zooecial cavity is about equal in diameter throughout. Diaphragms, few in number, not more than one to each zooecium, generally placed at the inner border of the mature portion of each tube which is 1 to 1.5 mm. thick. Mesopores small, irregular in form, about one-fourth as numerous as the zooecia.

The writer is in doubt about the systematic position of this species. It may belong to *Stenopora*, *Batostomella* or *Rhombopora*. When someone establishes the limits of these genera, it can be correctly placed. *Rhombopora crassa* Ulrich has a thicker cortical portion, no large acanthopores, and the zooecia are not vertical in the axial region. There are not enough large acanthopores to place it with *R. lepidodendroides* Meek; also, other characters, such as the zoarial form and quick transition from the immature to the mature region, make it dissimilar. The apertures are not like those of most species of *Batostomella*, but the walls, mesopores, and small acanthopores resemble to a degree the same of that genus. The apertures, acanthopores and mesopores as a whole seem to be nearer those of *Stenopora* than to either of the other genera. The species may be a *Rhombopora* related to *R. crassa* and *R. lepidodendroides*. Further, it may be a peculiar form of an old growth of the latter. Type specimens in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; South Bend, Nebraska.

Fenestella cyclofenestrata n. sp.

Pl. XXI. Figs. 1-3.

Zoarium a reticulate expansion apparently of large size; of a number of incomplete zoaria, each over 4 cm. across. Branches straight or slightly flexuous, average width 0.25 mm., twelve to fourteen in 5 mm., 0.35 mm. wide immediately below bifurcations which are far apart and with very acute angles; reverse face evenly and slowly rounded, smooth or faintly striated; the obverse shows a broad, evenly elevated area 0.07 to 0.1 mm. across; spines not observed to be present. Frequently the area is more elevated and appears as a broad carina.

Dissepiments on the reverse face, as wide as long, over one-half as wide as the branches, on a level with the latter, much expanded terminally; they and the branches slope evenly to the fenestrules; not much depressed and strong on the obverse. Fenestrules on the reverse, circular or subcircular, modified by the terminally expanded dissepiments, average 0.2 mm. long, about twelve in 5 mm.; a little longer and less wide on the opposite face.

Zooecia in two regularly alternating ranges (sometimes three for a short distance below a bifurcation). The two ranges are widely separated by the broad area. Apertures circular or subcircular, usually two, rarely three to each fenestrule, 0.08 mm. across, 0.12 mm. across including the peristome, with the peristome slightly less than their own diameter apart, twenty-four in five mm.

These specimens are not apt to be confused with any of the described species. The reverse face resembles, to a degree, that of *F. conradi* Ulrich, but is of smaller proportions and without perforated nodes. The circular to subcircular fenestrules, wide area or carina, and rather robust appearance serve to distinguish the specimens from related species. Some authors would classify this species with the genus *Polypora*. The name is suggested by the circular fenestrules of the reverse face. Type specimens in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; Bennett, Nebraska. Quite plentifully represented at that locality, being found in a thin layer of impure limestone, in the creek bed, about two miles below town.

Fenestella spinulosa n. sp.

Pl. XXI. Figs. 4, 5.

Zoarium a fan-shaped expansion, commonly found fragmentary. One complete abnormal zoarium, resembling *Ptilopora* in its mode of growth, is 4 cm. high by 3 cm. wide. Its main branches are 0.28 to 0.30 mm. in diameter and give rise, from their sides, at very acute angles, to smaller branches, 0.2 to 0.25 mm. wide; also, the latter may originate by bifurcation. Branches of normal zoaria, on the reverse, straight, cylindrical, faintly striated or granulose, 0.28 mm. wide, varying some in distance apart, usually about their own diameter apart, about nine or ten in 5 mm. The obverse face has a rounded carina, quite well elevated, bearing a row of conical spines 0.07 to 0.1 mm. in diameter at their bases in young growth, averaging 0.25 mm. distance from apex to apex, usually two to each fenestrule, disposed so that one occurs near the end of each dissepiment and one between; they about equal one series of zooecial apertures in number. In older growth the spines are larger, and quite obscure the apertures.

Dissepiments on the reverse, straight, cylindrical, with very little terminal expansion, not much depressed, average width one-third that of the branches; depressed on the obverse face. Fenestrules rectangular, vary in size, 0.35 to 0.45 mm. long by 0.2 to 0.3 mm. wide; not so regular on the obverse, only slightly modified by the zooecial apertures, nine and one-half to ten in 5 mm.

Zooecia small, in two alternating ranges, about two times their own diameter apart, subcircular, in some specimens pustuliform, others have faint peristomes, project little into the fenestrule, nineteen or twenty in 5 mm.

The species is nearest related to *F. sevellensis* Ulrich, from which it is not readily distinguished if the reverse face is viewed, except with worn specimens when the smaller zooecia show. The zooecia are larger than those of *F. parvipora* n. sp. The distinguishing features are the large spines on a carina. The obverse face is not very apt to be confused with other species. *F. limbata* Foerste has more prominent apertures and smaller proportions. Type specimens in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; Roca and Dawson, Nebraska. This is a common fossil in the Warner quarry one mile east of Roca.

***Fenestella parvipora* n. sp.**

Pl. XXI. Figs. 6, 7.

Zoarium an expanding foliar net work of medium size. Branches on the reverse, straight to sinuous, convex, finely striated if worn, more than their own diameter apart, average diameter 0.24 mm., nine or ten in 5 mm.; bifurcations at distances of 2 to 4 mm. Obverse face subcarinate; the carina is represented by a line on which occur very small nodes; nodes scarcely discernible, 0.04 mm. at bases, 0.15 to 0.21 mm. apart.

Dissepiments straight, long, cylindrical, about one-third as wide as the branches, not much depressed on the reverse face; depressed on the obverse. Fenestrules oblong, quite large for the size of the branches, average 0.5 to 0.55 mm. long, 0.31 mm. wide; the narrowest are 0.28 mm.; seven and one-half in 5 mm.

Zooecia small, in two alternating ranges, three or four to each fenestrule. Apertures very small, circular, pustuliform with rounded subconical peristomes, 0.09 mm. across including the peristome, face obliquely outward, more than their own diameter apart, 25 in 5 mm.

This species resembles *F. sevellensis* Ulrich in having a similar reverse face, but is distinct on account of the number, size and disposition of zooecia. It is not apt to be confused with another member of the genus. *F. gracilis* n. sp. has a definite carina with larger spines, larger apertures and very different fenestrules. The writer knows of no species of the genus with as small zooecia and zooecial apertures. Type in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; Roca, Nebraska.

***Fenestella gracilis* n. sp.**

Pl. XXI. Figs. 8, 9.

Zoarium a regular foliar expansion of large size as indicated by numerous incomplete specimens. Branches on the reverse, about equal in size, straight or slightly flexuous, spread little when bifurcating, appear cylindrical, with longitudinal striae; average width 0.25 mm., nine to twelve in 5 mm. The obverse face has a straight carina, 0.07 mm. wide, with rounded summit, bearing a row of sharp, conical

small spines with diameters of 0.07 mm. and placed at distances of 0.22 mm.

Dissepiments slightly expanded terminally, depressed some on each face, slightly on the reverse, 0.1 to 0.13 mm. wide in the middle, wider in older growth. Fenestrules quite regular in form, subrectangular, vary some in dimensions with different conditions of growth, modified little by zooecial apertures, average 0.65 mm. long by 0.25 mm. wide, long for the width, about six in 5 mm. A larger form has longer fenestrules.

Zooecia in two alternating straight ranges. Apertures with fairly prominent peristomes, about their own diameter apart, set close in against the carina, facing outward, four and rarely five to each fenestrule, twenty-three to twenty-five in 5 mm. The species resembles *F. dentata* Rogers but is not so robust. That species has eight branches in 5 mm., each being 0.4 mm. in diameter. The fenestrules average 0.9 mm. long by 0.3 mm. wide, with four in 5 mm. This species has more and smaller nodes as well as twenty-three to twenty-five instead of eighteen zooecia, for each range, in 5 mm. The fenestrules are shorter. Type in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; Roca, Nebraska.

***Fenestella polyporoides* n. sp.**

Pl. XXII. Figs. 6, 7.

Zoarium a strong reticulate expansion. Several specimens each 3 or 4 cm. high have been found. Branches robust, cylindrical, striated on the reverse, straight or flexuous, flexures bending to and away from the dissepiments, 0.35 to 0.4 mm. wide, 0.5 mm. below a bifurcation, six in 5 mm. The obverse face has a well developed carina 0.1 mm. across, somewhat flexuous, bearing a row of prominent nodes 0.5 to 0.6 mm. apart. Dissepiments expanded terminally about one-half as wide as the branches. Another form has smaller dissepiments and larger fenestrules; fenestrules subelliptical to subquadrangular, large in typical specimens, 0.9 to 1.05 mm. by 0.4 mm. inside measurement, eight in 1 cm.

Zooecia in two or three ranges, sometimes three for a short distance below a bifurcation, four or five in each range to the fenestrule, seventeen or eighteen in 5 mm.; apertures circular, 0.13 mm. across including the peristome, a little more than their own diameter apart, project very little into the fenestrule.

The species is related to *F. kansanensis* Rogers and *F. dentata* Rogers; *F. hurlingtonensis* Ulrich differs in the size of the nodes, but has as many apertures. Specimens sent to E. O. Ulrich were pronounced by him members of the genus *Polypora*. However, the writer is inclined to place them with the fenestellas. The main specific characters are found in the resemblance to the polyporae and in the large dimensions.

Position and locality: Coal Measures; Roca and Plattsmouth, Nebraska.

***Fenestella conradi* var. *compactilis* n. var.**

Pl. XXII. Figs. 1, 2.

Zoarium a very thick compact foliar expansion supported by a stalk and root-like processes. The best specimen secured is 4 cm. high by 2 cm. wide; the root-like supports are 1 to 2 mm. in diameter. Branches straight or slightly flexuous, unusually thick from obverse to reverse, close set, quite regular in form and size, average 0.35 mm. wide, 0.4 mm. below and 0.3 mm. immediately above a bifurcation, nine or nine and one-half in 5 mm.; reverse face smooth, without nodes, slightly smaller than the obverse, but not the difference noted in typical specimens of the species; striations show on the stalk and for a short distance out on the branches, especially when worn. Median carina of the obverse face not very prominent, rounded, straight or slightly flexuous, with small spines or nodes placed in two faint rows.

Fenestrules on the reverse, circular, slightly elliptical in young portions of the zoarium, 0.25 to 0.35 mm. across at the surface, much contracted and nearly obliterated deeper in the frond, eight and one-half or nine in 5 mm., a little longer and less wide on the opposite face.

Zooecia in two alternating ranges. Apertures circular, peristome faint or wanting, two and never three to each fenestrule, encroach slightly on the fenestrule, eighteen in 5 mm.

This variety may prove a distinct species. *F. sp. (?)* differs in mode of growth. Also the keels and reverse faces are dissimilar; the rounded irregular keel which at places shows two rows of small nodes brings to mind *F. binodata* n. sp. Type specimens in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; South Bend and Roca, Nebraska.

Fenestella sp. (?)

Pl. XXII. Figs 3-5.

Zoarium a regular rapidly or slowly expanding net work. The largest specimen, not complete, is 3.75 cm. high by 2.5 cm. wide. Branches rigid or flexuous, much the wider on the obverse face, narrowly rounded and thin on the reverse being 0.16 to 0.24 mm. wide, nine or ten in 5 mm. Carina quite prominent, thin, varying with the growth, about 0.06 mm. across at the top where it appears sinuous bearing a row of flattened nodes; nodes 0.1 mm. long by 0.06 mm. wide at the base, 0.2 to 0.3 mm. apart from apex to apex.

Dissepiments on the obverse, not constant in character, about 0.15 mm. wide, depressed, expanded terminally, modifying the fenestrules; on the reverse, slightly smaller, long and without much terminal expansion, on a level with and of the same character as the branches.

Fenestrules usually subcircular or elliptical on the obverse; larger on the reverse where they may be subquadrate and sometimes hexagonal, about as wide as long, average 0.4 mm. wide, decreasing in width towards the obverse face where they are 0.35 mm. long by 0.26 mm. or less wide; nine or nine and one-half occur in 5 mm.; except for the projecting apertures, they are subcircular or subelliptical on the obverse face.

Zooecia in two alternating ranges, of medium size. Apertures circular, two to each fenestrule, one placed at the end of each dissepiment with one between, a little more than their diameter apart including the not very definite peristome, project slightly into the fenestrule; eighteen to twenty in 5 mm.

The affinities of this species are with *F. conradi* Ulrich and *F. conradi* var. *compactilis* n. var. It differs from the former in having eighteen or twenty instead of twenty-three zooecia in 5 mm., two instead of two or three apertures to the fenestrule and a different character of fenestrule. On the reverse face, the branches are relatively much smaller compared with the obverse. The thin keel is also a distinctive feature. It differs from the new variety in mode of growth, character of keel, and in having a very different reverse face. The species is not apt to be confused with the latter. Type specimens in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; South Bend and Nehawka, Nebraska. The first specimen was collected at South Bend by Prof. E. H. Barbour, 1896.

Fenestella subrudis n. sp.

Pl. XXI. Figs. 10, 11.

Zoarium a foliar expansion of unknown size. Branches on the reverse, broadly rounded, granulo-striated, slight sinuous, quite closely approximated, 0.35 to 0.45 mm. wide, eight in 5 mm.; on the obverse, they are subcarinate and finished by a small carina which may be smooth or have inconspicuous nodes; carina 0.06 mm. across; nodes, if present, feebly elevated; a flattened area or face extends on each side of the carina down to the broadest part of the branch; these areas, slightly concave, are modified by the zooecial apertures.

Dissepiments on the reverse, short, wide, expanded terminally, narrowly rounded, not much depressed, 0.15 to 0.2 mm. wide; they vary more in size and are faintly striated on the opposite face.

Fenestrules elliptical to elongate-elliptical; average on the reverse, 0.5 to 0.55 mm. long by 0.24 mm. wide, slightly larger on the reverse, six in 5 mm.

Zooecia in two alternating ranges. Apertures circular, of medium size, 0.13 mm. across with peristome, a little more than their own diameter apart including the peristome, three to each fenestrule, seventeen or eighteen in 5 mm. The nearest related species is *F. missouriensis* Rogers which is not very dissimilar.

narrowly or slowly rounded, sides facing the fenestrules flattened, surface covered with granules 0.05 mm. across; a few circular accessory pores are present on this face; pores placed near the ends of the dissepiments, sometimes scattered over the surface, 0.14 mm. in diameter; branches close, average 0.7 to 0.8 mm. wide, 0.9 mm. just below a bifurcation, five in 5 mm.; obverse face quickly rounded, with large nodes along the center which cause it to appear thin; nodes readily observed by the unaided eye, irregular in form and size, 0.15 mm. wide by 0.3 mm. long at their bases, elevated, 0.4 to 0.5 mm. apart from apex to apex, in one regular row in young specimens, or in irregular rows in old forms.

Dissepiments on the reverse, short, granulose; much depressed and thinner on the opposite face. Fenestrules of the reverse, elliptical, 0.9 mm. long by 0.5 mm. wide, smaller deeper in the frond; on the obverse face, less regular, longer, narrower, 1. to 1.1 mm. long by 0.3 to 0.4 mm. wide, four in 5 mm.

Zooecia in four or five, sometimes six, alternating ranges. Apertures subcircular, 0.9 to 0.11 mm. across, one to one and one-half diameters apart; lateral ranges have thin peristomes; the middle ranges are quite obscured by the large nodes while the lateral ranges are not easily seen on account of the depth and the flattened surface. No Coal Measure species has the apertures more obscured; sixteen occur in 5 mm., with four in each range to the fenestrule.

This species is related to *F. ulrichi* n. sp., but is less robust and structurally different. The accessory pores of the reverse face serve as the basis for the name. Type specimens in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; Table Rock, Nebraska. The first specimen of the species was collected by Mr. H. H. Moore, 1900.

Polypora ulrichi n. sp.

Pl. XXIII. Figs. 6-10.

Zoarium a reticulate expansion of large size; branches on the reverse, stout, rigid, rounded; sides facing the fenestrules rounded or flattened, granulose; granules in faint lines. Branches average 0.9 mm. in width, 1.25 mm. just below and 0.75 to 0.8 mm. immediately above a bifurcation, six to eight in 1 cm.; obverse subcarinate, especially in young unworn specimens, with a row of large cylindrical nodes along the middle of the branch, nodes usually in a straight line, 0.5 to 0.7 mm. apart, 0.15 to 0.21 mm. in diameter, with blunt apices, larger and less regularly disposed in old forms.

Dissepiments depressed, subcarinate, thin and short on the obverse; larger, some wider, not much and sometimes not at all depressed, stout, one-third to two-thirds as wide as the branches, expanded terminally, and faintly granulose on the reverse.

Fenestrules on the reverse, subelliptical, 1.15 to 1.38 mm. long by 0.4 to 0.5 mm. wide, six to seven in 1 cm., not quite so long on the reverse. Zooecia quite large, in four to seven alte

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finer growth, a less binodate appearance and a larger number of apertures. The principal characters of this species are found in the double row of alternating nodes on a broad carina and in the robust appearance. Type specimens in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; South Bend, Weeping Water, and Roca, Nebraska.

***Polypora bassleri* n. sp.**

Pl. XXII. Figs. 8, 9; Pl. XXIII, Fig. 1.

Zoarium and expanding growth of medium size; branches not very straight, narrowly or evenly rounded on the reverse resembling, when narrow, *P. submarginata* Meek; evenly rounded on the reverse, with small or large spines distributed among the apertures about as in *P. spinulifera* Ulrich; spines located on thin zigzag ridges between the ranges or on a fairly even surface; about five branches occur in 5 mm., each having an average diameter of 0.7 mm., 0.8 to 0.9 mm. just below a bifurcation.

Dissepiments on the obverse, one-half as wide to as wide as long, about 0.35 mm. wide, broadly rounded, expanded terminally. Fenestrules elliptical to oblong, average 0.9 to 1.0 mm. long by 0.4 wide on the obverse, with four in 5 mm., larger on the reverse face.

Zooecia in three to six, usually closely placed alternating ranges, commonly four above a bifurcation; five, rarely four, sometimes six, in each range to the fenestrule. Apertures circular, 0.11 mm. across, one and one-half diameters apart, nineteen or twenty in 5 mm. with peristomes around the apertures of the lateral ranges; zooecia of the other ranges with peristomes or open into small depressions between the zigzag lines which may separate the ranges; apertures usually less than their own diameter apart from those in the adjacent or alternating ranges. This species resembles *P. approximata* Ulrich, but is structurally different. The growth in one form is more diffuse the reverse face of which resembles smaller *P. submarginata* Meek. In fact some of the specimens commonly referred to that species belong here. The other form of growth is nearer *P. approximata* and *P. spinulifera*. The ranges of zooecia are more crowded in old than in young growth. Little area or space is left between the alternating ranges. *P. approximata* Ulrich is more robust and differs structurally. The name is given in honor of Mr. R. S. Bassler who has rendered the writer valuable assistance. Type specimens in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; Louisville, Weeping Water, Nebraska.

***Polypora reversipora* n. sp.**

Pl. XXIII, Fig. 2-5.

Zoarium a flat foliar expansion of large size. Branches on the reverse, stout, flexuous, bending into and away from the dissepiments,

has dissepiments so thin. The name is given on account of the distance the apertures are apart in the series. Type in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; Louisville, Nebraska.

Thamniscus pinnatus n. sp.

Pl. XXIV. Figs. 3-8.

Zoarium a flabellate frond varying much in size; one complete specimen collected at Roca, is 3 cm. high, and 4 cm. wide; all other zoaria found are smaller and average higher than wide; the base is subcircular from which a stalk ascends to support the frond. The main branches (sometimes one branch) ascend in a zigzag manner, giving off short pinnae or lateral branches at the bends and bifurcate at distances of from 4 to 10 mm. Another form of growth is less zigzag in character. It is more like *T. octonarius* Ulrich, but has been pronounced distinct by the author of that species. Branches subcircular to subelliptical in section, wider than thick, especially at a distance from the stalk, 1 or 2 mm. in width, more than their own diameter apart; form and size vary in different regions and with the condition of growth; the obverse face is more convex than the reverse. The pinnate branches divide with rounded angles. Pinnae alternately places, about 2 mm. apart on each margin of the branch, 1 mm. apart longitudinally along the branches between the bifurcations, usually about 1 to 1.5 cm. long.

Zooecia increase rapidly in number of ranges, from three, four or five, to seven or eight, and infrequently nine between the bifurcations. Apertures small, 0.07 mm. in diameter, circular, pyriform in worn specimens, arranged in definite longitudinal series, and quite regular diagonal series; fifteen occurring in 5 mm. longitudinally, four and one-half in 1 mm. diagonally; in some well preserved specimens they are placed on faint oblique ridges.

The branches divide with rounded angles, but the ranges of zooecia separate with acute angles with a wedge-shaped area between. Peristome, in perfect specimens, horse-shoe-shaped, elevated, lifted into a small spine on each side of the aperture. On the lower side of the aperture the peristome widens to wholly or partially surround a sub-oval depression which, in perfect specimens, is .14 mm. wide by .18 mm. long.

This species is related to *T. octonarius* Ulrich, but has more prominent apertures and a much more diffuse growth. The figures represent two types of growth and what may be two distinct species, yet the writer prefers, for the present at least, to place them under the same name. One form is less pinnate and more like Ulrich's species. Type specimens in the museum of the University of Nebraska, Lincoln, Nebraska.

Locality and locality: Coal Measures; Bennett, Roca and Dawson, Nebraska. *Preservation:* represented at Bennett.

***Thamniscus palmatus* n. sp. (Provisional.)**

Pl. XXIV. Fig. 9.

Zoarium a small palmate expansion, 11 mm. wide and 12 mm. high, supported by a circular base from which ascends a short dividing stalk which divides into primary and secondary branches; branches about 0.65 mm. wide, quite straight, evenly convex, nearly in a plane, about their own diameter apart, bifurcate with rounded acute angles; no dissepiments or fenestrules are present.

Zooecia extend from the sides of the branches and seem to show prominent projecting apertures, 0.21 to 0.25 mm. apart, with thirteen occurring in 5 mm. Worn portions of the zoarium show them arranged in three to five ranges. Owing to its mode of growth, no other described bryozoan is apt to be confused with this species. As yet only one specimen has been secured. It was sent to E. O. Ulrich who pronounced it of strange and peculiar growth, and expressed his regrets that the obverse face did not show. Type in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; Roca, Nebraska.

***Cystodictya anisopora* n. sp.**

Pl. XXV. Figs. 1-5.

Zoarium a bifurcating stipe, 0.8 mm. thick, 1. to 1.25 mm. or more wide between the bifurcations, 1.6 mm. wide just below a bifurcation, subelliptical in section; one margin is sharp and the other rounded resembling, to a degree, the same of *C. inequimarginata* Rogers. Bifurcations not numerous, at wide angles.

Zooecial apertures in four or five linear series on each face of the zoarium, usually five, subcircular to elliptical, elevated on the side of the wider margin when perfect, vary in size in the different series, about 0.14 mm. wide by 0.18 to 0.2 mm. long in the row nearest the wide margin, smallest in the row nearest the narrow margin, about twice their own diameter apart longitudinally. (More in the fifth range) closer laterally. The first range has seven apertures in 5 mm., the third eight and the fifth nine and one-half; no longitudinal ridges are present; apertures in well preserved specimens sometimes on prominent transverse ridges, except the less prominent apertures of the fifth range, which are near the narrow margin. The apertures of this range are located between the small ends of the transverse ridges and alternate with the apertures of the fourth range. The transverse ridges are higher, when present, and broader near the wide margin and decrease in width and elevation towards the narrow margin.

Zooecia of the two faces of the zoarium separated by a definite mesotheca, lie close together against the latter and are incompletely separated from each other by vesicular tissue. The main body of each zoarium is vertical, from which a vestibule or neck curves quickly to the surface.

This species is related to *C. inequimarginata* Rogers, but is more robust and shows, when perfectly preserved, transverse ridges. There are four and usually five instead of three or four longitudinal series of apertures, also seven instead of ten large apertures occur in 5 mm. in the range nearest the broad margin. The name is based on the unequal apertures. Type specimens in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; Roca and Ashland, Nebraska.

Cystodictya lophodes n. sp.

Pl. XXV. Figs. 6, 7.

Zoarium a bifurcating stipe, subcircular or slightly elliptical in section, width 1. to 1.1 mm. between bifurcations, 1.5 mm. or more at bifurcations; angle of bifurcation wide. Nonporiferous margins narrow, equal or about equal in width. Zooecial apertures in linear series between longitudinal ridges. Ridges 0.2 mm. apart. Four or five, rarely three, subalternate ranges of apertures occupy each face of the zoarium. The number is increased to five or six below each bifurcation. Apertures elliptical, rather large, 0.12 to 0.14 mm. wide by 0.18 mm. long, about twice their own diameter apart longitudinally, about the same distance apart in each range, do not differ much in size, eight in 5 mm. longitudinally in each range, open into trough-like depressions between the longitudinal ridges, with or without peristomes. Vesicular tissue composed of small irregular vesicles is closely packed about the zooecia.

The species is distinguished from *C. anisopara* n. sp. by having more equal apertures, no transverse ridges and equal margins. Also, the zooecial apertures open between longitudinal ridges instead of being elevated on the oblique ridges as they are in perfect specimens of that species. Type specimens in the museum of the University of Nebraska, Lincoln, Nebraska.

Position and locality: Coal Measures; Roca, Nebraska.

Description of Plates.

PLATE XVIII.

Fistulipora carbonaria var. *nebrascensis* n. var.

1. Surface enlarged.
- *2. Tangential section, drawn to a scale of 1 mm.
Cyclotrypa (?) *barberi* Ulrich n. sp.
3. Surface enlarged, $\times 22$.
4. Specimen outlined, natural size.
5. Transverse section, $\times 22$.
6. Transverse section, near the center of the stem.
7. Vertical section of a small branch, $\times 12$.

*Observe the millimeter scale which is used for most drawings.



8. Surface enlarged.

Meekopora prosseri Ulrich n. sp.

9. Specimen outlined, natural size.

PLATE XIX.

Meekopora prosseri Ulrich n. sp.

1. Surface enlarged, $\times 6$.
2. Tangential section of an old example, $\times 30$.
3. Transverse section of a young specimen, $\times 18$.
4. Tangential section, $\times 18$.
5. Vertical section, $\times 18$.
6. Section representing basal parts of zooecial tubes, $\times 6$.

Botostomella leia n. sp.

7. Specimen outlined, natural size.
8. Portion of the surface enlarged.
9. Tangential section.
10. Vertical section.

PLATE XX.

Stenopora heteropora n. sp.

1. Vertical section.
2. Tangential section from deep in the zoarium.

Stenopora distans n. sp.

3. Surface enlarged.
4. Tangential section from near the surface.
5. Vertical section.

Stenopora (?) *polyspinosa* n. sp. (Provisional).

6. Specimen outlined, natural size.
7. Outline of transverse section.
8. Surface enlarged.
9. Tangential section.
10. Vertical section.

PLATE XXI.

Fenestella cyclofenestrata n. sp.

1. Portion of reverse face of young growth enlarged.
2. Portion of reverse face of older growth enlarged.
3. Obverse face of small branch.

Fenestella spinulosa n. sp.

4. Portion of reverse face enlarged.
5. Portion of obverse face enlarged.

Fenestella parvipora n. sp.

6. Portion of obverse face, enlarged less than in Fig. 7.
7. Portion of reverse face enlarged, scale to the left.

Fenestella gracilis n. sp.

8. Portion of reverse face enlarged.
9. Portion of obverse face enlarged.

Fenestella subrudis n. sp.

10. Portion of reverse face enlarged.
11. Portion of obverse face enlarged.

PLATE XXII.

Fenestella conradi var. *compactilis* n. var.

1. Reverse face.
2. Portion of obverse face enlarged.

Fenestella sp. (?)

3. Portion of reverse face, enlarged.
4. Portion of reverse face of irregular growth.
5. Portion of obverse face, enlarged.

Fenestella polyporoides n. sp.

6. Portion of reverse face enlarged.
7. Portion of reverse face of worn specimen enlarged.

Polypora bassleri n. sp.

8. Outline, portion of reverse face of diffuse growth.
9. Portion of obverse face of diffuse form enlarged.

PLATE XXIII.

1. Portion of obverse face, regular form of old growth.

Polypora reversipora n. sp.

2. Reverse face, outlined.
3. Portion of reverse face enlarged.
4. Transverse section of branches.
5. Portion of reverse face enlarged.

Polypora ulrichi n. sp.

6. Reverse face, outlined.
7. Portion of reverse enlarged.
8. Portion of obverse enlarged.
9. Profile of a branch.
10. Transverse section of a branch.

PLATE XXIV.

Polypora remota n. sp.

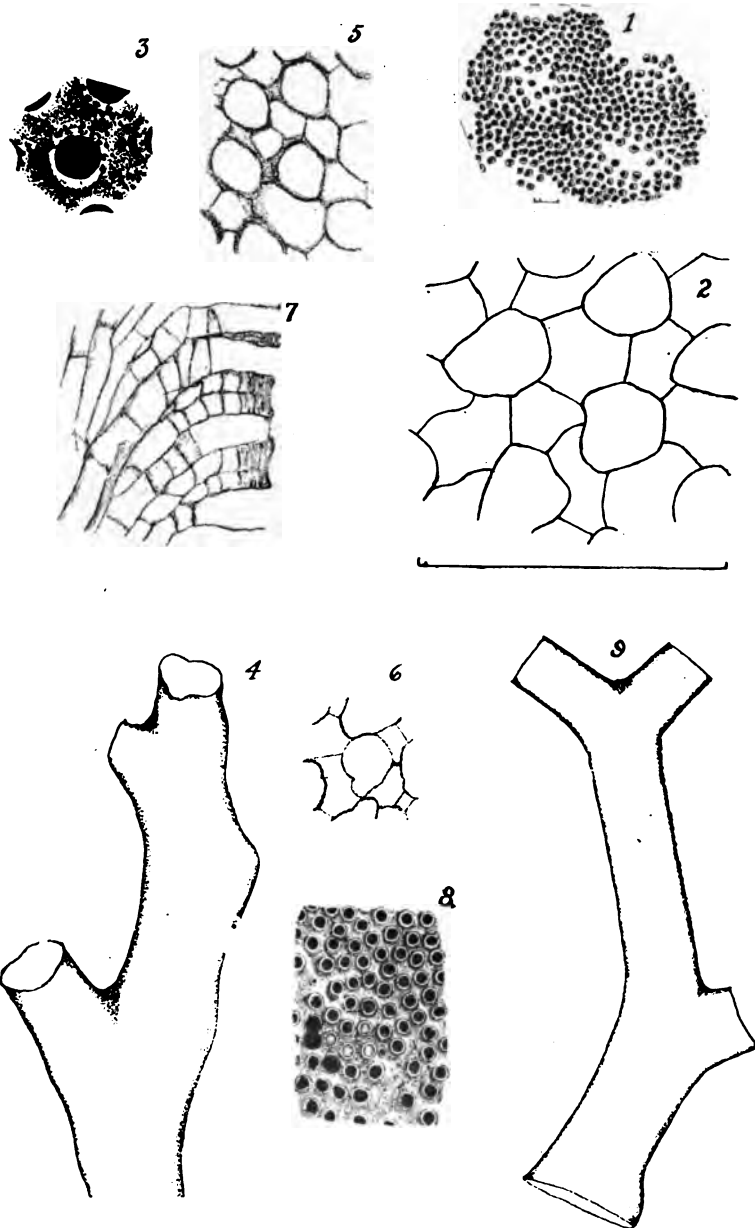
1. Portion of obverse face enlarged.
2. Horizontal section, enlarged.

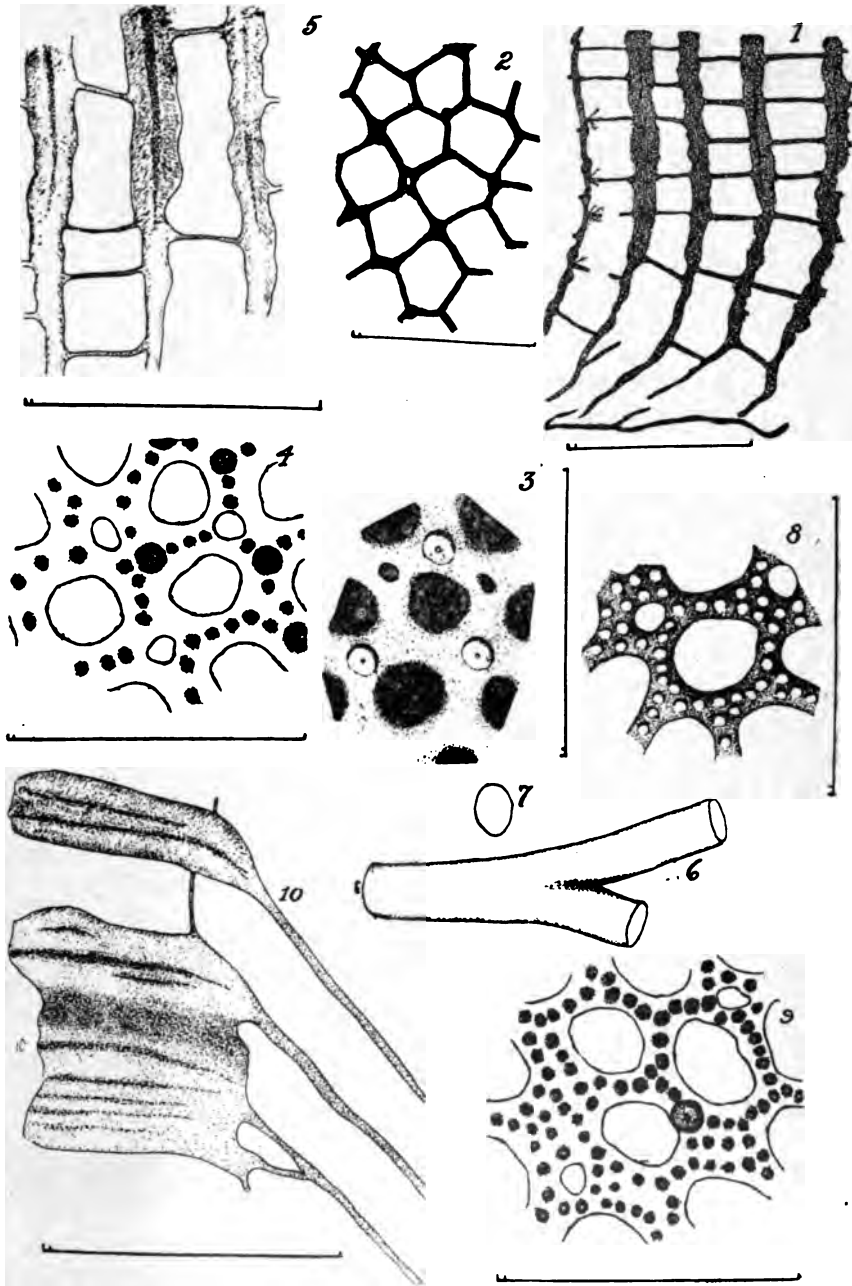
Thamniscus pinnatus n. sp.

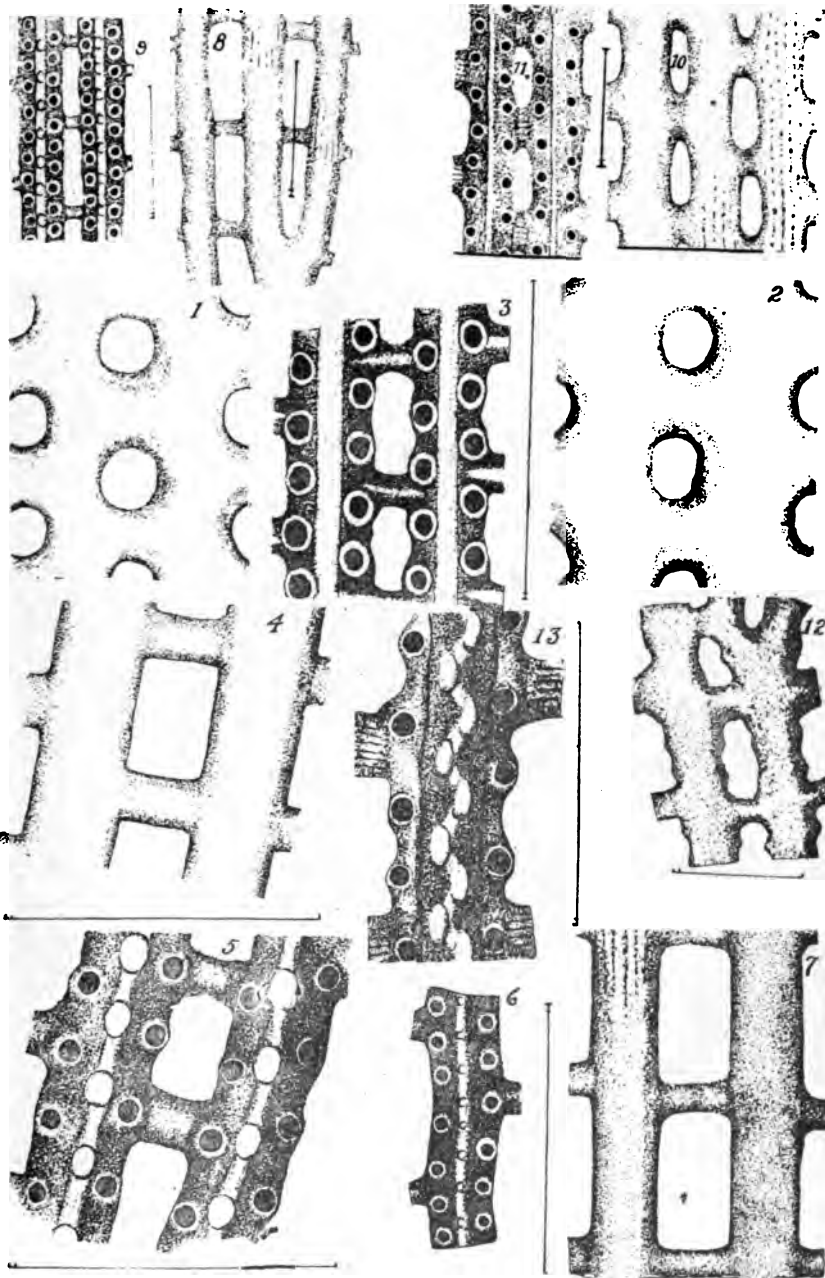
3. Outlined reverse face of one form of growth, natural size.
4. Outlined reverse face, natural size.
5. Outlined reverse face, natural size.
6. Outlined reverse face of form most like *T. octonarius*.
7. Portion of obverse face enlarged.
8. Horizontal section, enlarged.

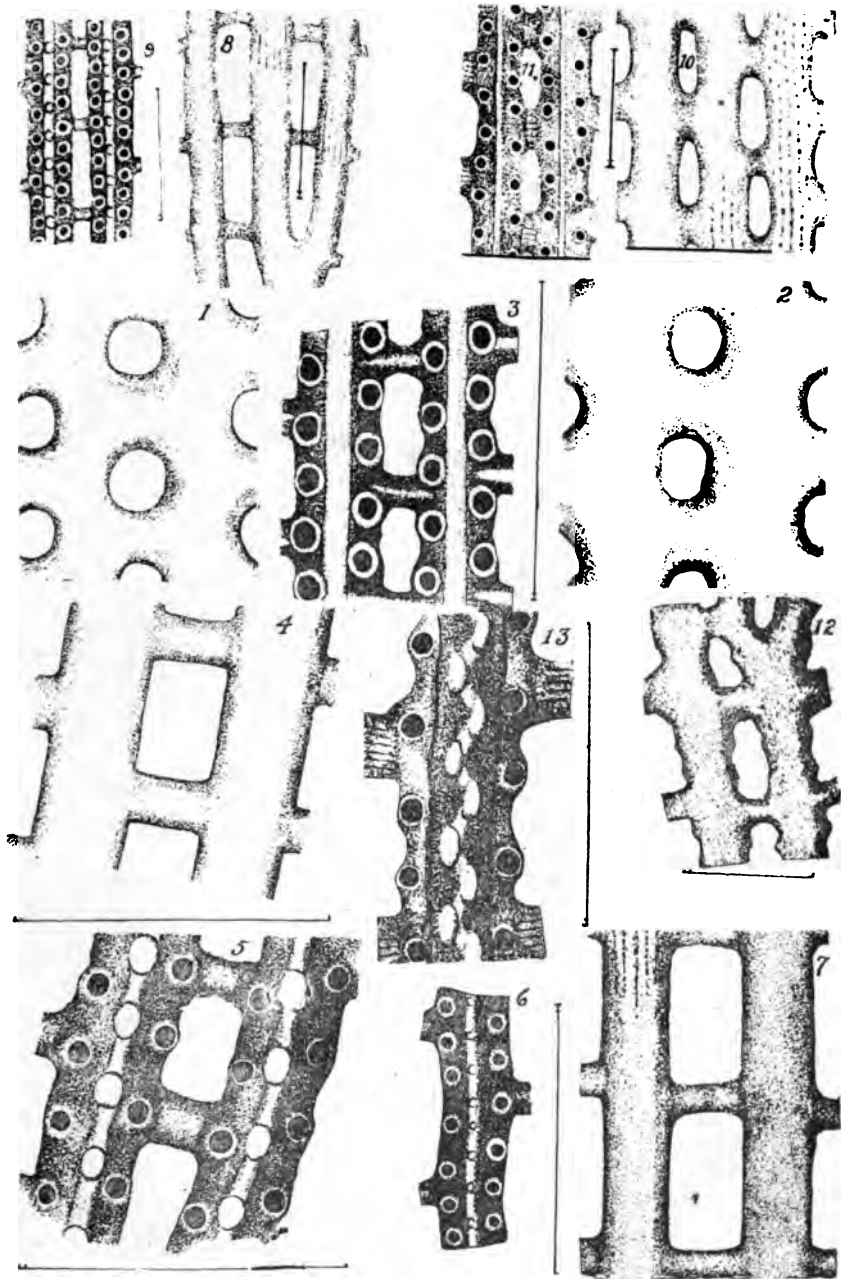
Thamniscus palmatus n. sp. (Provisional)

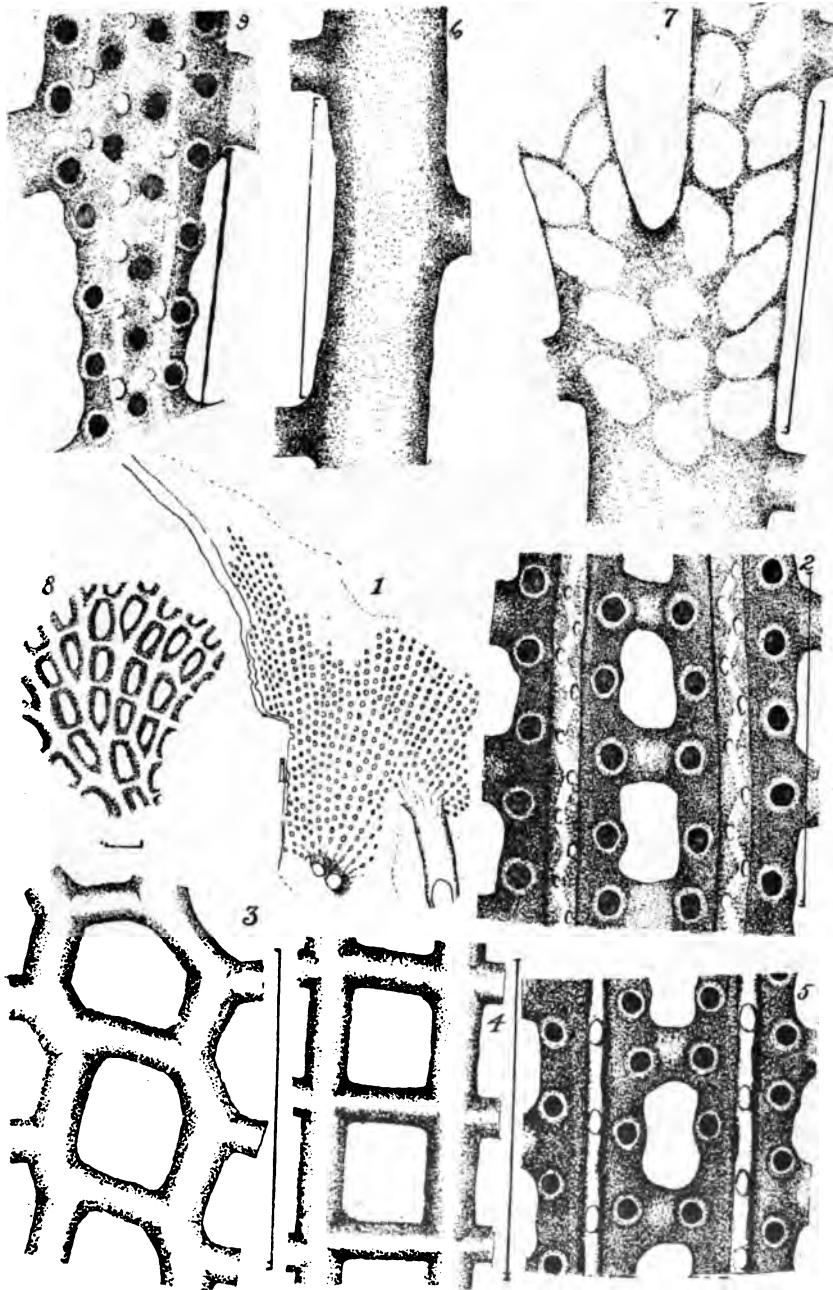
9. Reverse face.

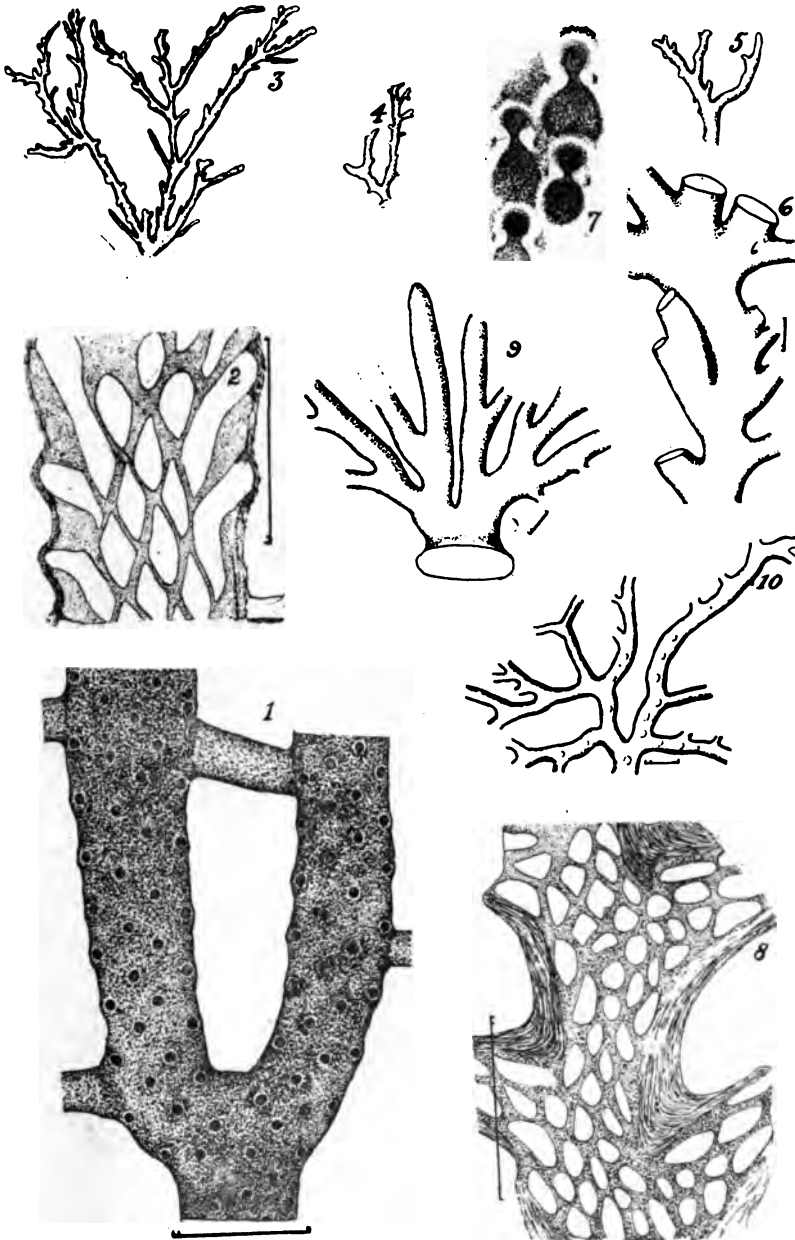


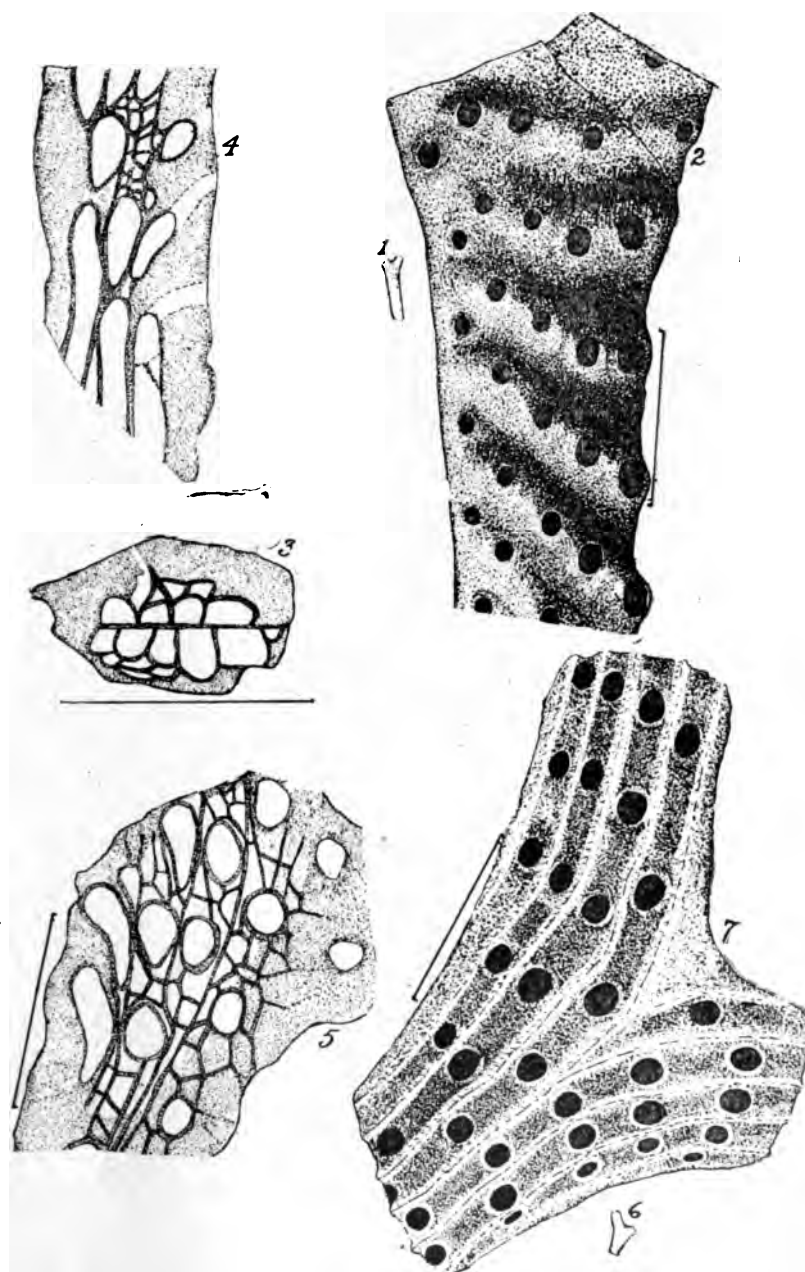


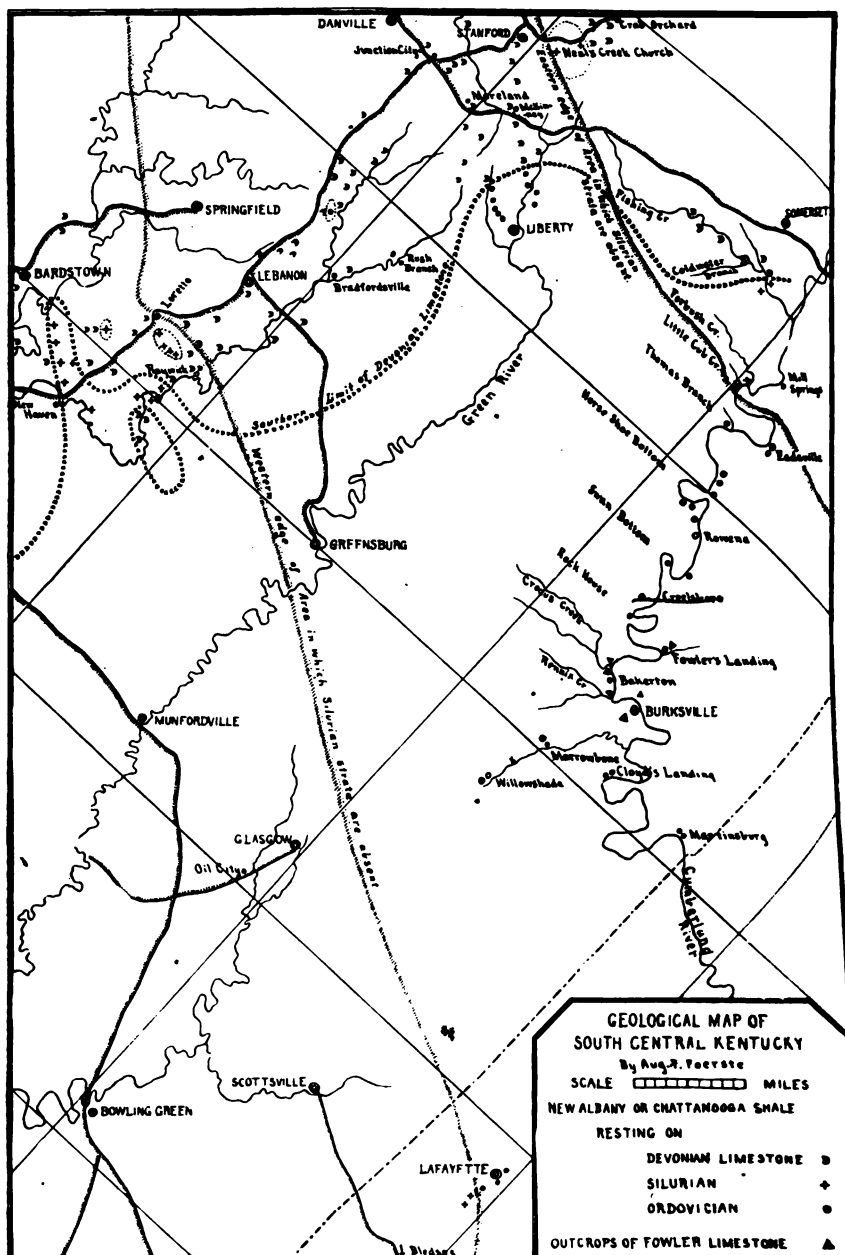












Thamniscus sevilensis Ulrich.

10. Reverse face of a diffuse form.

PLATE XXV.

Cystodictya anisopora n. sp.

1. Outline of specimen, natural size.
2. Enlarged branch.
3. Transverse section of a branch.
4. Vertical section.
5. Oblique tangential section.

Cystodictya lophodes n. sp.

6. Outline of specimen, natural size.
7. Enlarged branch.

THE CINCINNATI ANTICLINE IN SOUTHERN KENTUCKY.

By AUG. F. FOERSTE, Dayton, O.

PLATE XXVI.

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A. THE CINCINNATI ANTICLINE.	
<i>Its trend.</i> —The Cincinnati anticline is a low fold extending from southwestern Ohio through central Kentucky and Tennessee. Its general trend is about 25 degrees west of south. In Ohio its crest passes about 15 miles east of Cincinnati; in Tennessee, about 40 miles east of Nashville.	
<i>Its existence in early Devonian times.</i> —The fold originated during the Paleozoic era. Some geologists feel convinced that evidence of its existence can be detected even in early Ordo-	

vician times. To the writer, the evidence adduced does not appear as yet to be sufficient. Moreover, the arguments in favor of the existence of the anticline in later Ordovician times or during the Silurian period do not seem as yet to be altogether conclusive. However, the presence of this fold in early Devonian times may be definitely established by means of the evidence now at hand. This evidence consists in the presence of Silurian strata along the flanks of the anticline and in their absence along the crest. In consequence, the later Devonian deposits rest directly upon Ordovician strata along the crest of the anticline, but upon Silurian formations along its flanks. This evidence is found in south central Kentucky and in northern Tennessee.

In central Kentucky, the Devonian rests on Silurian formations, along the western flank of the anticline, as far east as Loretto and Raywick in the western part of Marion county. East of these localities for a distance of 40 miles, as far as Stanford in the western part of Lincoln county, the Devonian rests directly upon the Ordovician. Southeast of Stanford, however, near Neals Creek church, the Silurian is exposed, and from this point eastward and northward along the eastern flank of the anticline, the Devonian rests again upon the Silurian.

In northern Tennessee, the most eastern exposures of Silurian rocks along the western flank of the Cincinnati anticline occur several miles west of Lafayette in Macon county. Thence eastward for a distance of more than 50 miles, both along the northern border of the Central Basin of Tennessee and along the Cumberland river, the Devonian rests directly upon the Ordovician. The most western exposures of Silurian rocks along the eastern flank of the anticline occur near the mouths of Little Cub and Forbush creeks in Wayne county, Kentucky.

The areas within which the Silurian strata are absent, between Loretto and Stanford, and between Lafayette and Little Cub creek, lie along the crest of the present Cincinnati anticline. The absence of the Silurian in these areas may be accounted for most readily by assuming that the anticline existed at least before the deposition of the later Devonian formations now found in place. Whether the anticline existed already in

Silurian times, so that Silurian formations were never deposited along its crest, or whether the anticline originated at a later date, the absence of Silurian strata being due to subsequent removal by erosion, must be determined by other evidence.

The western boundary of the area within which Silurian strata are absent is necessarily conjectural between Raywick and Lafayette. Recent operations within the oil field near Glasgow, however, have suggested the presence of Silurian strata immediately beneath the New Albany or Chattanooga Black slate.

B. THE SILURIAN EAST OF THE ANTICLINE IN SOUTHERN KENTUCKY.

The distance between Neals Creek church and Little Cub creek is much less than that between Raywick and Lafayette and the determination of the eastern boundary of the area within which Silurian strata are absent is assisted both by the numerous exposures between Stanford and Liberty, at which the Devonian rests directly upon the Ordovician, and also by the recent discovery of Silurian strata about 5 miles west of Somerset, along Fishing creek.

This discovery was made by Prof. Arthur M. Miller of the State College of Kentucky. The exposures occur on both sides of Fishing creek, chiefly north of the bridge, for a distance of about 2 miles, and along a branch flowing north of the home of V. L. Gossett and entering Fishing creek from the west. The Silurian here is 17 feet thick. North of the bridge, the lower 7 feet are massive, have a bluish color, and are very fine-grained, without a trace of fossils. Lithologically they resemble very much the lower part of the Clinton as exposed between Bardstown and Raywick, west of the anticline in central Kentucky. Similar rock occurs at the base of the Clinton in many parts of Garrard and Madison counties, east of the anticline. Above this massive rock occur 10 feet of distinctly bedded limestone. At the top of this section, a layer about 1 foot thick contains large crinoid heads, such as are characteristic of the Clinton, numerous specimens of a coral identified provisionally as *Enterolasma calycula*, and one specimen each of *Dalmanella elegantula*, *Calymmene Vogdesi*, and *Whitfieldella cylindrica subquadrata*. The Whit-

fieldella is characteristic of the Osgood formation. A slight unconformity is believed to exist between the Clinton and the Osgood formations, an intermingling of fossils occurring at the base of the Osgood. A greater thickness of the Osgood beds is seen at numerous points farther up the creek but no measurements were recorded.

Near the mouth of Forbush creek, the Clinton is 14 feet thick, and is overlaid by the layer containing large crinoid beads and also the Whitfieldella. The Osgood is a foot and a half thick. The Whitfieldellas are common at a poor exposure near the home of William Richardson.

Just below the mouth of Little Cub creek, the Clinton is 16 feet thick. Crinoid beads and Whitfieldellas are very common in the layer immediately above. The Osgood formation is 17 feet thick and is formed of the following beds in ascending order: limestone, 3 feet 4 inches; green clayey shale, 2 feet 6 inches; clayey limestone, 2 feet; greenish clayey shale, about 9 feet.

C. THE SOUTHERN EXTENSION OF THE DEVONIAN ALONG THE ANTICLINE.

The Devonian in the area occupied by the Cincinnati anticline consists of limestone overlaid by black slate.

Devonian limestone.—At Louisville, the Devonian limestone may be divided into two formations; the lower or Jeffersonville limestone, about 20 feet thick; and the upper or Sellersburg bed, 15 feet thick. According to Edward M. Kindle,* the Jeffersonville limestone may be traced southward into Kentucky, but the Sellersburg bed has not been seen south of Louisville. The Sellersburg bed corresponds most nearly to the Hamilton of New York, while the Jeffersonville limestone is most nearly equivalent to the Corniferous or Onondaga limestone.

In Ohio, the Hamilton has been identified as far south as Delaware and Franklin counties. The Corniferous, however, may be traced farther south, to the western part of Pickaway county.†

* E. M. KINDLE. The Devonian and Lower Carboniferous Faunas in southern Indiana and central Kentucky. *Bulletin of American Paleontology*, No. 12, 1899.

† *Geol. Sur. of Ohio Rep. of Progress in 1870*, pp. 285-286.

It seems, therefore, that along both flanks of the Cincinnati anticline the Corniferous extends farther south than the Hamilton.

It is probable that most of the Devonian limestones between the Ohio river and central Kentucky belong to the Corniferous. However, no attempt has been made as yet to keep separate the faunas belonging to different horizons and to determine their geological position accurately. It is possible therefore that other horizons, above or below the Corniferous may be present, especially at those localities where the Devonian limestone has a thickness of 20 feet or more.

Devonian limestone is frequently exposed on the crest of the Cincinnati anticline between Loretto and Stanford, and also along the many branches of Rolling Fork, and in the vicinity of Moreland and McKinney. It is absent however on the crest of the anticline along the Cumberland river and in northern Tennessee. The probable southward extension of the Devonian limestone is indicated on the accompanying map as well as our present knowledge will permit.

The Devonian limestone extends farther south along the flanks of the anticline than along its crest.

In Tennessee, Devonian limestone occurs at the bridge west of Pegram, about 18 miles west of Nashville. At the thickest part of the section 11 feet of Corniferous are overlaid by 1 foot of Hamilton.

On a recent visit to the area along Fishing creek, east of the crest of the Cincinnati anticline in Kentucky, in company with Prof. Arthur M. Miller, Devonian limestone was discovered outcropping for a distance of about 7 miles along the creek. The most southern outcrop detected occurred along the branch separating the farms of Mrs. Al Loyal and Sol Jones. Here the limestone is $3\frac{1}{2}$ inches thick and is overlaid by coarse sandy material, half an inch thick. About a quarter of a mile northward, along the Sulphur Spring branch, the Devonian is $2\frac{3}{4}$ feet thick; it consists, in descending order, of coarse sandstone, 6 inches; fine grained bluish limestone, 1 foot 9 inches; and brecciated rock, 4 to 6 inches. A mile and a half northward, just above John Freeman's house, the Devonian limestone is 4 feet thick; most of it is white and crinoidal, containing Cyathophylloid corals and large Spirifers.

A short distance northward, just above the home of Taylor Brock, the Devonian is 12 feet thick; at the top the rock is cherty; just beneath it contains Cyathophylloid corals; near the base $5\frac{1}{2}$ feet of the rock is massive and finegrained. A short distance northward, just below the mouth of Coldwater branch, the Devonian is 17 feet thick, consisting in descending order of brecciated brownish rock, 9 inches; white limestone, 1 foot; thin limestone layers, $2\frac{1}{2}$ feet; massive limestone, $7\frac{2}{3}$ feet; cherty limestone, $2\frac{1}{2}$ feet; and finegrained limestone, 3 feet. The Devonian was traced 3 miles above the mouth of Coldwater branch, and is said by the natives to occur 2 miles farther northward, in the vicinity of Adams mill.

At a number of localities fossils are not uncommon. Among these a specimen of *Amphigenia* suggests the Corniferous age of the rock. It is a pedicle valve, 8.4 cm. long, 4.3 cm. wide at a point about $\frac{1}{3}$ of the length of the shell from the beak, and 2.6 cm. deep; the sides are strongly compressed so that the shell appears more elongate than most of the specimens referred to *Amphigenia elongata*. The cast of the spondylium is distinctly shown. The specimen was found at the Sulphur Spring locality.

It is possible that the sandy layer, 3 inches thick, at the base of the black shale on Forbush creek corresponds to the sandstone at the top of the Devonian at its most southern exposures on Fishing creek.

New Albany or Chattanooga Black Shale.—East of Fishing creek, along the road leading from Somerset west across the iron bridge and passing the house of V. L. Gossett, the New Albany or Chattanooga Black shale is 46 feet thick. It decreases gradually in thickness westward. At Burksville it is 30 feet thick; at Martinsburg, 22 feet; west of the crest of the anticline it varies considerably and irregularly in thickness, from 28 feet as a maximum to 4 or 5 feet, and occasionally is absent altogether.

The Devonian along Fishing creek probably rests upon Osgood strata.

D. THE ORDOVICIAN EAST OF THE ANTICLINE IN SOUTHERN KENTUCKY.

The Richmond formation.—Along the branch north of the home of V. L. Gossett, 27 feet of Ordovician rock are exposed

below the Clinton. It is chiefly a clayey section with occasional layers of harder clayey limestone. The lower 2 feet of the exposure contain *Streptelasma rusticum* (= corniculum of most authors). The largest specimen found was 8 cm. long. In Ohio, Indiana, and north central Kentucky this species was common in the Richmond epoch, occurring even in the lowest parts of the group. It has not however been discovered in the Lorraine. This suggests the Richmond age* of the Ordovician exposures along Fishing creek. The other fossils found, *Hebertella sinuata*, *Pterinea demissa*, and *Byssonychia radiata*, are found both in the Richmond and in the Lorraine epochs.

At the mouth of Forbush creek, the Clinton is underlaid by a bluish clayey Ordovician rock, 21 feet thick, containing poorly preserved specimens of *Columnaria*. This fossil is common at certain levels in the Richmond formation in Kentucky and Indiana, but apparently is absent in most of the Lorraine. Possibly some of the beds in Nelson and Marion counties, Kentucky, which contain *Columnaria* may be referred to the top of the Lorraine. At the mouth of Little Cub creek, the Clinton is underlaid by clayey Ordovician rock, 19 feet thick, in which no fossils were found.

The reference of the Ordovician rocks immediately beneath the Clinton, along Fishing creek, and at the exposures mentioned along the Cumberland river, to the Richmond is therefore merely provisional.

The total thickness of rock along the upper course of the Cumberland river to be referred to the Richmond is unknown.

The Lorraine formations.—The next lower rock consists of thin bedded clayey calcareous material, in some places changing to a thin bedded sandy limestone, without fossils. At the bend north west of Thomas branch, the exposure of this bed is 22 feet thick. On the western side of Horse shoe bottom, it measures 28 feet. The total thickness is unknown.

Beneath the thinbedded rock occurs a massive clayey calcareous rock, usually about 10 feet thick. At the most northern point on the river, northwest of Thomas branch, this bed contains *Heterospongia subramosa* (identified by E. O. Ulrich), and a large form of *Platystrophia lynx*. The *Platystro-*

*JOHN M. NICKLES. The Geology of Cincinnati. *Journal, Cincinnati Soc. Nat. Hist.*, vol. xx, No. 2. 1902.

phia is fully as large as the form of *Platystrophia lynx* which is characteristic of the Mount Auburn bed in the upper third of the Lorraine as defined by John M. Nickles. The form most characteristic of the Mount Auburn bed has a hinge line considerably shorter than the greatest width of the shell. The bed contains also a second form, with a hingeline equaling or exceeding the greatest width of the shell. This form occurs not only in the Mount Auburn bed, but also in the overlying Warren bed, and in the underlying Corryville bed. It is this more widely distributed form of *Platystrophia lynx* which occurs in the massive bed along the Cumberland. Both forms are confined to the upper half of the Lorraine in Ohio, Indiana, and Kentucky; they do not occur in the Richmond. Hence the massive bed is identified as Lorraine. *Heterospongia subramosa* occurs both in the Richmond and in the upper Lorraine in Marion county, Kentucky.

Below the massive bed occurs a clayey calcareous rock which often forms high steep bluffs at the river's edge. It contains the same form of *Platystrophia lynx* as the massive bed immediately above, but the form occurs in vastly greater numbers, being occasionally abundant at all levels; usually however they are common only at lower levels and are much less common or even absent in the upper third of this bed. The bed is referred to the upper half of the Lorraine. Its total thickness is unknown. Northwest of Thomas branch only the upper 17 feet of this bed are exposed. Farther down the river, however, occur sections in which this bed equals and exceeds 50 feet in thickness.

Below the *Platystrophia* beds occur a series of less clayey layers, often consisting of fairly well bedded limestone. Two miles above Rowena, at the beginning of the high cliffs on the north side of the river just below Masons branch the limestone contains *Orthorhynchula linneyi*. This species seems to occur also in the same limestone southeast of the Horseshoe bottom, half a mile east of Difficult creek. This form is characteristic of the Fairmount bed in the lower half of the Lorraine. Hence the limestone along the Cumberland, in which the *Orthorhynchula* is found is identified with the lower Lorraine. This limestone contains more numerous and a greater variety of fossils than any other part of the Ordovician section along the crest of the anticline in southern Kentucky.

The Cumberland sandstone.—In 1877, Prof. N. S. Shaler gave the name Cumberland sandstone* to a series of rocks along the Cumberland river. No section is described. Typical exposures are said to be located above Burksville, in Cumberland county, and thence the sandstone extends in a narrow area up the Cumberland to the southwestern border of Pulaski county, and down the river to the southern edge of Kentucky. The sandstone is stated to range considerably in thickness, and to attain thicknesses of 50 and even 100 feet. It is described as finegrained, commonly of greenish color, and entirely barren of organic remains.

It is a difficult matter to determine what an author intended to include under any term when no section is described and when no locality is mentioned at which the rock occurs typically, with the practical exclusion of other rocks to which the same description might readily apply. Under these circumstances it must be assumed that the rock which topographically is most conspicuous, and which geographically has the same general extension must have been the rock designated.

The most conspicuous rock of Ordovician age between Burksville and Pulaski county, and the one which has the most general extension is the series consisting of the *Platystrophia* bed, the *Heterospongia* bed, and the overlying thinbedded clays of clayey limestones. These are all referred here to the Lorraine. While the *Platystrophia* bed frequently contains fossils, these fossils are often absent in the upper part of the beds, or are very inconspicuous, owing to the fact that they never weather out of the clayey matrix, so as to be readily detected, but are seen only as cross-sections, where the rock has broken across the fossil, due to scaling in consequence of weathering. While these cross-sections could be readily detected if the rock were closely examined, they might readily escape attention during a more hasty survey, especially during a rapid reconnaissance of the territory along a large river in a sparsely inhabited country, designed for the study of only the more striking economic features.

The rock identified as Richmond at Forbush and Little Cub creeks does not occur at the other exposures visited farther down the river.

* *Geological Survey of Kentucky*, 1877, vol. iii, New Series; consult also, 24th Report, Indiana Survey, pp. 57 to 60.

The Fowler limestone,* occurring at various localities between Fowlers Landing and Burksville, usually is located higher up, above the steeper parts of the cliffs which are within easy reach of persons landing from a skiff. Moreover the Fowler limestone and the overlying Ordovician rock usually weather away more readily than the underlying section, so that they are less frequently exposed, and rarely form any conspicuous part of the cliff sections.

The writer is therefore of the opinion that the major part of the rock designated as the Cumberland sandstone by Prof. N. S. Shaler must have been of Lorraine age, and if any part of the Richmond is to be included under this name this is due rather to accident than to the original intention of the author. The Richmond localities at Forbush and Little Cub creeks, and the Fowler limestone and overlying beds near Burksville are altogether too inconspicuous parts of the river sections along the Cumberland to have given rise to this name.

The writer is even more convinced that most of the beds in Casey, Marion, Boyle and Lincoln counties belong to the Lorraine. In the western part of Marion county, and in Nelson county, less than 30 feet of Richmond beds have been identified in any section. The unfossiliferous beds in the vicinity of Lebanon belong to the Lorraine. This is also the horizon of the unfossiliferous beds at Moreland.

On the eastern side of the anticline, in the vicinity of the Clinton outcrops, it is almost certain that both Richmond and Lorraine rocks have been included under the name of Cumberland sandstone. Near Concord, east of Maysville on the Ohio river, the Richmond exceeds 164 feet in thickness. West of Spencer, on the railroad east of Mount Sterling, about 50 miles southwest of Concord, the Richmond is about 62 feet thick. At the base, *Streptelasma rusticum* is common. Twelve feet above the base, *Rhynchotrema capax* and *Strophomena planumbona* occur. Twenty feet below the top, *Strophomena sulcata* was found. The top of the beds containing the form of *Platystrophia lynx* with a long hingeline occurs 46 feet beneath the base of the Richmond. The intervening rock is almost unfossiliferous, but stratigraphically belongs to the top

* AUG. F. FOERSTER. Silurian and Devonian limestones of Tennessee and Kentucky. *Bull. Geol. Soc. of Am.*, vol. xii, 1901.

of the Lorraine. Even if the Richmond continues to decrease southward in Madison, Garrard and Lincoln counties it is probably not entirely absent in any of these counties although fossils may be extremely difficult to find. It was only by accident that the fossils in the Richmond west of Spencer were discovered. Even in the immediate neighborhood of Spencer the beds at the same horizon failed to reveal any fossils. It is therefore extremely probable that in the immediate vicinity of the Clinton outcrops in Madison, Garrard and Lincoln counties, the upper part of the rock included by various authors in the Cumberland sandstone belongs to the Richmond, while the sections at a greater distance consist chiefly or entirely of the top of the Lorraine.

E. THE SALUDA OR MADISON BED.

The bed described as the Madison bed* in the Indiana reports forms the top of the Richmond section. It includes all the material overlying the coral beds, the latter forming the base. These beds usually consist of large numbers of *Columnaria alveolata*, *Columnaria halli*, and *Calopoecia cribiformis*. The name Madison bed has been utilized also by other writers for other beds. To these authors must be conceded the priority of usage. It is therefore considered desirable to change the name of the beds at the top of the Richmond, hitherto called the Madison beds; the same Saluda bed is therefore introduced, taken from Saluda creek, 6 miles south of Hanover, Indiana. While the coral bed is practically absent along Saluda creek, the section nevertheless is sufficiently distinct to enable any one to draw the line between the nearly unfossiliferous base of the Saluda bed and the richly fossiliferous beds of the Richmond immediately beneath. While the name may be taken from another locality, the typical exposures must ever remain those at Madison, since nature in distributing her most typical exposures has not always followed the laws of geological nomenclature.

* 21st Annual Rep. Indiana Survey, 1897.

ON SOME JURASSIC FOSSILS FROM DURANGO, MEXICO.

By DOUGLAS WILSON JOHNSON, New York.

While making an examination for coal in certain formations west of Mapimi, state of Durango, Mexico, Edgar F. Tuttle, E. M., secured a few fragments of ammonoids which were sent to the Geological Department of the Columbia University. These fossils were given to the writer for identification, and the following notes are offered regarding their occurrence and age.

Quoting from Mr. Tuttle's letter, the fossils were found at San Pedro del Gallo, a town about fifty miles west of Mapimi, occurring in limestone near an underlying bed of bituminous and calcareous shale. This shale is exposed over a considerable area, and consists of alternate thin layers of the bituminous and limy material, the former sometimes becoming quite thick, and where exposed by shallow wells, smelling perceptibly of the bituminous matter. The town of Gallo is situated at the western border of the area over which the shales are exposed, (the area being some four thousand feet across the strike), near the contact with the limestone band in which the fossils occur. The whole formation has a westerly dip. The fossils are few and fragmentary.

Of the four ammonoids sent by Mr. Tuttle one fragment is too poorly preserved to admit of identification. The costae are simple, broad and rounded, and show uncertain evidence of terminating in nodes along the ventro-lateral angle, while even more uncertain is the possible occurrence of nodes midway between this and the umbilical angle. The writer can find no type to which the *apparent* features of this fragment correspond, and is inclined to regard it as a new species, altho it is too badly worn and broken to be determined with certainty.

Another fragment, well preserved as to detailed features, but too small to show distinctive characters, is evidently one of the Perisphinctidae, possibly *Perisphinctes potosinus* Castillo and Aguilera, described from Rancho Alamitos, Sierra de Catorce, San Louis Potosi.* The costae are compressed and

* "Fauna Fossil de la Sierra de Catorce, San Louis Potosi," por Antonio del Castillo y Jose G. Aguilera. *Boletin del Instituto Geologico de Mexico*, Num. 1, p. 31, lam. xvii, fig. 1; lam. xxiv, fig. 2.

prominent, and directed obliquely forward. Bifurcation takes place in some of the costae at least, two or three of them showing the beginning of the division just where the shell was broken.

A fairly good impression of one of the medium sized *Perisphinctidae* corresponds closely with the specimen which Castillo and Aguilera described from Tutotepec, Distrito de Huanchinango, Puebla, and compared with *Perisphinctes balderus* Oppel.* Various fragments from Catorce, San Louis Potosi, were also supposed to belong to this species. Our specimen shows the trifurcations in the last whorl mentioned by Castillo and Aguilera, has the same (or possibly one less) number of costae on this last whorl, while the costae on the first whorls are more marked than those in the last. In size of shell they agree closely. The characters of the ventre are not shown. Both our specimen and those of Castillo and Aguilera differ from the figures of *Ammonites* (*Perisphinctes*) *balderus* Oppel by Loriol† in that the trifurcations of the costae are absent in the latter.

The last specimen is a portion of the outer whorl of *Perisphinctes mazapilensis* Castillo and Aguilera.‡ The type specimens were described from Arroyo de los Alamitos, Sierra de Catorce, San Louis Potosi; and Sierra de los Tajos o Zuloaga, Mazapil, Zacatecas. Our specimen shows some twelve costae, all regularly bifurcate except two, in which the posterior branch of the bifurcation suffers a new bifurcation a little above the point of the first one. In respect to this occurrence the two sides of the whorl are not symmetrical, the costa on the one side being thus trifurcate, while its continuation on the opposite side is bifurcate. As a result the succeeding forward costae are no longer opposite, but alternate, the two branches of the bifurcated costa on the one side passing over the ventre, not to reunite as usual in an opposite costa, but one branch passing to a costa slightly behind the proper position of such an opposite one, while the other passes to the adjacent costa slightly in front of such position. This continues until a trifurcation on the opposite side re-establishes the

* *Idem.*, p. 24, lam. xi, fig. 1.

† *Mem. Soc. Paleont. Suisse*, vol. v. p. 94, pl. xv, fig. 7 et 8.

‡ *Bol. Inst. Geol. Mex.*, Num. 1, p. 23, lam. x.

usual order. The entire shell must have been about 125 mm. in diameter.

In none of the specimens are the sutures shown.

The above named fossils are referred to the Upper Jurassic by Castillo and Aguilera. This points to the presence of Upper Jurassic limestones and bituminous and limy shales near San Pedro del Gallo, state of Durango, Mexico. In the *Bosquejo Geologico de México** it is stated that the Upper Jurassic and Cretaceous series occurs in the north-central part of the state of Durango, being fossiliferous in the vicinity of the town of Gallo, but that lack of data would not permit the classification (separation) of this formation. It is believed that the town of Gallo here referred to, and shown on the map about fifty miles slightly southwest of Mapimi, is the same as the San Pedro del Gallo from which our fossils come. The abbreviation of such names is usual, and Mr. Tuttle himself speaks of the town simply as Gallo in one place in his letter.

On the geological map of Mexico published in 1889 under the direction of professor Castillo, a small portion of the map in the vicinity of Gallo is colored blue, indicating Jurassic at this point. In the revised edition of this map, however, "re-formada con nuevos datos en 1891, 1892 y 1893," no Jurassic is shown at this point at all, Cretaceous alone being represented. It would appear that the "new data" led to the rejection of the idea of the Jurassic's occurring in this locality. If such is the case, the present note may serve to confirm the correctness of the older map in this regard.

*Palacontological Laboratory,
Columbia University,
November 18, 1902.*

* *Bol. Inst. Geol. Mex.*, Nos. 4, 5 y 6, p. 20.)

**DESCRIPTION OF A NEW SPECIES OF CLADODUS
(*C. FORMOSUS*) FROM THE DEVONIAN
OF COLORADO.**

By O. P. HAY, New York.

This species is based on a single specimen which was collected in the year 1900 by Mr. Whitman Cross of the U. S. Geological Survey. It was found in the Ouray limestone of the Needle Mountain quadrangle, at the northwest edge of Lime mesa, which is on the south slope of the Needle mountains, in western Colorado. Dr. George Girty, who has described the invertebrate fossils of this formation, informs us (U. S. Geol. Surv. 20th Ann. Rept., pt. 11, 1900, p. 35.) that it belongs to either the late middle or early upper Devonian. The fossil is borne on a piece of limestone which was found loose on a ledge of the Ouray limestone; but there are no higher formations at that part of the mesa, as I am informed by Mr. Cross; hence its origin is unquestionable.

As to the character of the fauna of this formation, Dr. Girty informs me through Mr. Cross that it is a clearly defined Devonian fauna, containing no Lower Carboniferous forms.



Fig. 1. *Cladodus Formosus*. Hay. $\times 2$.

The tooth is firmly imbedded in a hard limestone, the anterior face being exposed; and I have not ventured to remove it. Consequently, the character of the posterior face is unknown. The tooth (Figure 1, $\times 2$) is of median size. The height of the principal cusp, measuring from the lower line of the base, is 10.5mm. The base from one extremity to the other equals 15mm. Seen from the front the extremities of the base are narrow. In the midline the base is rather deeply sinuated; while between the sinus and the extremities the outline is convex.

From the base spring the large median cusp and two pairs of small lateral cusps. The width of the principal cusp,

at the notch between it and the inner lateral cusps, is 4.5mm. The lateral outlines are nearly straight to the smooth rounded tip. There is a very gentle sigmoid flexure. The anterior face is rather strongly convex, becoming flattened toward the base, and at length somewhat excavated. The lateral edges appear to be sharp. The anterior face is occupied by sharp costæ, about 20 at the base and about 10 just below the tip. The costæ near the outer border of the base of the large cusp disappear soon in the edges of the cusp. The costæ all come down low on the base of the tooth.

The lateral cusps are small, conical, and rather slender. The inner pair are somewhat the larger. All are ornamented with a few sharp costæ.

From *Cladodus girtyi* Hay, of the Coal-measures of Colorado, this species differs especially in the shorter lateral cusps. *C. concinnus* Newb. of the Cleveland shales of Ohio, has the median cusp higher than the length of the base of the tooth. *C. intercostatus* has on each side of the anterior face a strong ridge running parallel with the cutting edge.

Dr. Eastman has suggested a resemblance of this new species to some varieties of *C. springeri*, especially with some forms of it from Russia. The latter species belongs to the Lower Carboniferous, and it is quite unlikely that it will occur as low down as the middle Devonian. Most of the specimens of *C. springeri* possess several cusps on each side of the main cusp, and the base lacks the median sinus. Dr. Eastman kindly informs me that *C. primigenius*, of the Devonian of Russia, has also several cusps on each side of the main one, and that the latter is slenderer, and the base not so sinuate.

*American Museum of Natural History,
New York, Oct. 10, 1902.*



FIG. 1.



FIG. 2.



FIG. 3.

**CONCRETE EXAMPLES FROM THE TOPOGRAPHY
OF HOWARD CO., IOWA.**

By S. CALVIN, Iowa City, Ia.

PLATE XXVII.

With reference to the distribution of geological formations, the location of Howard county, Iowa, is one of unusual interest. Along the Upper Iowa, or Oneota river, in Albion township, the county possesses, topographically, some of the characteristics of the Driftless Area, an area from which it is separated by a comparatively narrow marginal zone of Kansan drift. The margin of the Iowan drift passes through the northeastern part of the county, and so northeast of a certain definite line which can be easily traced, the country is rolling Kansan drift covered with loess; while by far the larger part of the county—the part lying southwest of the line referred to—belongs to the level or gently undulating, uneroded, loessless Iowan plain. One of the interesting geological features of this region is the absence of the Niagara limestone or any representative of the Silurian system, for here the Devonian overlaps upon the shales and shaly limestones of the Ordovician. But it is with the topography of the county that this paper will specifically deal.

What Norton calls the loess margin or loess moraine of the Iowan drift passes through the northeast part of Howard and divides the county into two very distinct topographic areas, each of which is again divided into smaller areas according to the extent to which glacial deposits are developed. The line separating the two principal areas passes from Minnesota into Iowa near the northwest corner of section 11, Forest City township, from which point it bends to the west and then turns nearly due south, traversing the eastern edge of section 10. After passing into section 15 the line makes an abrupt bend to the east, passes through the northern part of section 14, whence, veering southward, it maintains, with some minor deflections and sinuosities, a general southeasterly course until it leaves the county a few rods south of the northeast corner of section 36, Albion township. The area north and east of this line is comparatively small; only about 22 square miles, all told, are here included; but within this limited space there is

more of topographic interest than in all the rest of the county. On one side of this line is an old, leached, oxidized and deeply eroded drift overlain by loess; on the other side the surface is occupied by a young, unaltered, uneroded drift upon which there is no loess, but large granite boulders, of types wholly absent from the northeastern part of the county, give character to long vistas of gently undulating plain. The small northeastern area may be called the *Loess-Kansan*, the larger area to the southwest is the *Iowan*.

The Loess-Kansan Area.—Leaving out of consideration for the present the valley of the Upper Iowa or Oneota river, the Loess-Kansan area presents a series of rounded hills separated by ravines which have been cut in the surface of a sheet of drift by flowing water. All the topographic features of the region—the hills, ravines and even the deep stream valleys—are due to the carving and shaping effects of ordinary surface drainage. Outside the river valley, the topography is a direct product of the run-off of the ordinary storm waters. The underlying drift, as already intimated, is what has been called in recent geologic literature the Kansan. The surface of this ancient glacial deposit, by reason of long exposure to rains and other meteorologic agents, was deeply trenched, and the sculpturing resulted in producing, on a small scale, a mature type of erosional topography (Fig. 1, Pl. XXVII). At the time of maximum development of the ice sheet which deposited the comparatively recent Iowan drift, the carved surface of the old Kansan till which lay exposed outside the border of the Iowan ice, was covered with a thin veneer of the fine clay called loess. This loess was moulded over the inequalities of the eroded Kansan surface. The deposit was doubtless thicker in some places than in others, but, after all, the thickness was practically uniform, the variations being no greater than would be found in a mantle of snow laid down in comparative quiet upon an uneven surface. And thus it was that by the deposition of the loess the characteristics of the old topography were not veiled or obscured to any noteworthy extent. The hills and ravines remained during and after the process of loess deposition in the same relative positions and with the same relative heights. It is true that some minor features of the present topography are due to trenches

cut in the recently deposited loess, but in general the amount of erosion since the loess was laid down as a comparatively thin mantle over the trenched surface of ancient Kansan, is so small as to be scarcely appreciable. For a measure of the amount of erosion that has taken place since the period of loess deposition we may turn to the Iowan plain, for in the matter of age the Iowan drift is contemporaneous with the main body of the loess of this part of the Mississippi valley. The fact is, that with very few and very unimportant exceptions, the surface of the younger drift remains practically as the glaciers left it. Over ninety-nine per cent. of its area and more, the erosion of the surface, from the withdrawal of the Iowan ice to the occupation and cultivation of the territory by the white man, would have to be expressed by zero. Except in some trifling and unimportant details, therefore, the topography of the Loess-Kansan region is not due to erosion of the loess, but is controlled by surface forms which had been developed long before any loess was deposited. All deep cuts for roads or railways or for whatever purpose made, in Loess-Kansan areas of Iowa, whether in Howard county or in other portions of the state, show that the present loess surface is essentially parallel with the old eroded surface of the Kansan till. At the risk of seeming to indulge in unnecessary reiteration it may be stated that all field evidence is overwhelmingly in favor of the view that the topography of Loess-Kansan areas—such topography as is shown in figure 1—is fundamentally pre-loessial. The loess did not level up the surface as some have supposed. Over the greater part of the area in which it is distributed it has not been eroded to any appreciable extent since it was laid down. Its thickness and general relations to the surface have never been very different from what they are to-day.

A marked departure from the type of topography generally prevailing in the Loess-Kansan area of Howard county is found in the charmingly picturesque valley of the Upper Iowa or Oneota river. This valley is a deep trench cut into the indurated rocks. In some of its characteristics it resembles the valleys of the Driftless Area. The topography of the greater part of the northeastern division of Howard county is post-Kansan in age. It was developed, as already noted,

by erosion of the drift surface during the long intervals between the retreat of the Kansan ice and the deposition of the loess. On the other hand the valley of the river is older than the Kansan; it is preglacial. There are no indications that this part of Iowa was ever occupied by the more ancient ice sheet that, over the major portion of the state, preceded the Kansan; but that the valley was deep and open almost as it is to-day when the ice of the Kansan stage was melting, is attested by terraces of rusty Buchanan gravel at various points along the stream. A concrete illustration of these old gravels, deposited by floods from the melting Kansan ice and rising not more than twenty or twenty-five feet above the level of the water in the present channel, is found south of the bridge at Florenceville, near the center of section 10, Albion township.

The Iowan Area.—The Iowan area embraces much the larger part of Howard county. There was a time, however, when the whole county, and practically the whole surface of Iowa, presented an appearance topographically like the northeastern part of Albion township. At a date very recent compared with the age of the Kansan drift, glacial conditions recurred; a new ice sheet coming from the northwest flowed over the eroded Kansan surface, obliterating the old erosional topography as far as it went, distributing new and fresh material, and leaving the surface, when the ice melted, in the form of plain with long, low, sweeping undulations. Constructive work of glacier ice in spreading out and piling up morainal detritus, was the potent factor in developing the resulting topography. Erosion was in no way concerned. Erosion has had practically no effect in modifying the ice-moulded surface of the Iowan drift since the disappearance of the Iowan ice.

Iowan glaciers covered all of Howard county except the few square miles of the Loess-Kansan area already described. The Iowan ice advanced to what is now the boundary line between the two topographic areas of the county, and there stopped. On one side of that line the topography is old, on the other side it is young. Along the boundary line there is usually a great thickening of the loess; and as ordinarily seen from the Iowan plain the margin is marked by a series of hills which, from a distance, present the appearance of a terminal

moraine (Fig. 2, Pl. XXVII). From the summit of the marginal ridges the observer looks in one direction upon a tumultuous series of erosionally developed and well rounded hills and ridges (Fig. 1, Pl. XXVII); in the other direction the landscape is an uneroded plain stretching away to an uninterrupted horizon, as level as a sea (Fig. 3, Pl. XXVII).

The typical characteristics of the Iowan plain are best illustrated on the broad, flat divides between the drainage courses. The region having its center at the southeast corner of Saratoga township, may be cited as a concrete example of the ideal Iowan plain. But all portions of the county lying southwest of the Iowan-Loess boundary, and not immediately adjacent to streams, present the type of topography illustrated in figure 3. The surface is everywhere a plain slightly modified by elevations and depressions. As intimated above, such inequalities and irregularities as are present are due to the manner in which the drift material was arranged by the action of the Iowan glaciers, and not to any subsequent shaping or carving by drainage waters. Drainage is as yet imperfectly developed. There are in fact no drainage channels in the inter-stream areas. The storm waters simply flow off along broad, shallow, concave sags or so-called sloughs, the surfaces of which gradually blend into the low, broadly rounded swells which constitute the higher and better drained portions of the surface.

The permanent streams of the Iowan area, in the southwestern three-fourths of the county, flow in shallow depressions broadly concave from side to side, the margins of the depressions blending imperceptibly into the general Iowan plain. This is the condition presented by the Wapsipinicon and Little Wapsipinicon in Wayne township and by Crane creek in Saratoga, Howard and Paris townships. These ill defined valleys, however, are all in a sense remnants of a pre-Iowan, even of a pre-Kansan, topography which has been modified by deposits of drift. The streams are simply following ancient valleys which are almost completely filled. Along all these streams there are beds of ferruginous, oxidized Buchanan gravels which show that here were drainage courses when the Kansan ice was melting. The gravels rest on Kansan drift with which the old valleys, probably preglacial, were

partly filled, and are in turn overlain by Iowan drift. The gracefully curving surfaces of valleys and uplands are sprinkled with Iowan bowlders. Nearly all the streams of this southwestern area have their origin within the limits of the county, and they are practically branchless so far as development of tributary channels is concerned. Broad "sloughs," in place of eroded creek beds, serve to collect the waters from the adjacent slopes. While the main drainage courses seem to have been largely determined by the position of preglacial valleys, the post-Iowan streams have accomplished very little in the way of erosion. They have neither valleys nor flood plains in the ordinary sense. They run in simple shallow trenches cut only a few feet below the level of the surface on which they began to flow after the withdrawal of the Iowan ice.

The facts bearing on the relative age of the Kansan and Iowan stages of glaciation, presented by the topography of the county we are considering, are consistent with all the facts which may be gathered from other portions of the state. The Kansan drift is deeply eroded; it was deeply eroded before the loess was deposited upon it. Taking the state as a whole, the entire Kansan surface, with the exception of a small undissected plateau here and there on the divides, was similarly trenched and carved by erosive agents. Mature erosional topography, with reliefs ranging from fifty to 200 feet, was developed by water carving of the drift surface, before the loess period began. Since the time of the loess, since the withdrawal of the Iowan ice, the erosion of the surface of the Iowan drift is too small to be measured, too small for relative numerical expression. The erosion of the old drift surface in the inter-Kansan-Iowan interval was certainly many hundreds of times as great as the erosion of the Iowan surface in all post-Iowan time. If any other measure of the relative age of the two drift sheets of Howard county be applied, the same astonishing results are reached. In the valley of the Turkey river at New Oregon, for example, there is a terrace of old, altered, rusty Buchanan gravel deposited when the Kansan ice was waning. About a mile above New Oregon there are young terraces of sand and fine gravel of late Iowan age, as fresh as if the material had been deposited by last season's floods. The same thing occurs at scores of places. At Iowa City, in the

valley of the Iowa river, there is a bed of old, rotted, ferruginous Buchanan gravel about thirty feet above the present water level. Down in the valley—the difference in height being a measure of the erosion which took place in the interval—there are extensive terraces of perfectly fresh sands which were deposited when the Iowan ice was melting a few miles farther up the stream. Whether comparisons be made on the leaching and segregation of the limy constituent of the two drifts, on the ferrugination and oxidation of the surface, on the rotting or decay of the surface boulders, or whatever the test employed may be, the changes wrought by time in the Iowan are too near to zero for satisfactory numerical expression; the changes in the Kansan are astonishingly great. If it should be claimed that the Kansan is a hundred times as old as the Iowan, I know of no facts at present that would disprove the claim. If some one should estimate the age of the Kansan as fifty times as great as that of the Iowan, I should be compelled to acknowledge that the estimate is very conservative.

Description of Plate XXVII.

Figure 1. View in the Loess-Kansan area, northeastern part of Howard county, Iowa, showing the type of topography developed by preloessial erosion of the ancient Kansan drift.

Figure 2. The loess margin or loess moraine at the border of the Iowan drift in section 26, Albion township, Howard county, Iowa. The level space in the foreground is a part of the Iowan plain.

Figure 3. A typical portion of the Iowan plain in section 7, Oak Dale township, Howard county, Iowa.

GEEST.

By W. J. MCGEE, Washington, D. C.

[From the Eleventh Annual Report, U. S. G. S., Part 1, pp. 277-280, 1889-90.]

Despite its extent and its accessibility, the superficial mantle of rock débris has received comparatively little attention; it was too common to inspire the enthusiasm of research in the local student, and like the drift, of a generation past, was by many regarded only as an annoying obstacle to investigation of the underlying rocks. Yet within recent years many American chemists and geologists have found it a worthy subject of study. Hunt has well elucidated the conditions of its or-

igin, and has seen within it a record of chemic activity varying through the ages with changes in atmospheric conditions and climate; Pumpelly has seen within it a possible source of vast æolic deposits; Julien has ably set forth the influence of the humus acids in decomposing rocks and producing soils, and has, like Hunt, seen within the products a record of variable activity in the rock destruction and considerable changes in the climate of the earth during the geologic periods; Hilgard, Shaler and others have investigated the products of rock decay as the most important source of soils; Chamberlin and Salisbury have made a classic study of the origin and physical composition of the residuary clays and loams of a definite territory and Russell has summarized the work of his predecessors, pointed out that the products of rock decay vary in volume with the latitude, and inferred that they represent secularly constant activity in the rock-destroying process. The local characteristics of the extensive mantle of rock débris within this country have also been set forth by a score of geologists in half the states of the Union.

Perhaps because of its universality in many lands and its prevalence in nearly all, the product of rock decay has no commonly accepted appellation. Pumpelly indeed groups the phenomena as "residuary products of a secular disintegration";* Chamberlin and Salisbury combine them as "residuary products";† and Russell speaks of "residual clay," "residual deposits," "residua," etc.;‡ but the expressions are manifestly employed as descriptive terms rather than specific appellations. Broadhead designates such material as "local drift,"§ and Kinahan applies the term "meteoric drift";|| but these expressions, too, are employed rather in a descriptive than in a denotative way, and moreover they are misleading in that, where typically developed, the materials are not drifted. Many varieties of rock débris indeed have descriptive names:—"adobe," "gumbo" (applied to disintegrated Cretaceous and Tertiary shales as well as to a Pleistocene deposit), etc., are common terms in this country; "terra rossa" is

* *Am. Jour. Sci.*, 3d Ser., vol. 17, p. 135.

† *Sixth Ann. Rep. U. S. Geol. Survey*, 1885, p. 230.

‡ *U. S. Geol. Survey Bull.* 52, pp. 13, 23, and elsewhere.

§ *Geol. Surv. Mo.*, 1874, pp. 64, 98, and elsewhere.

|| *Jour. of the Royal Geol. Soc. of Ireland*, 2d ser., vol. 4, part 3, pp. 115-121

equally well known in southern Europe; "regur" is the common name of a prevailing soil, and "laterite" the accepted designation for a peculiar ferruginous phase of the prevailing product of rock decay in peninsular India; and the "black earth" of Ukraine and "chernojem" of the Ural region are well known; but the group into which these phenomena fall is singularly nameless, alike among the students and the tillers of the earth.

The product of modern river action is everywhere recognized by some form of its classic appellation, alluvium; the distinctive but ever-varying deposit first studied on the banks of the Rhine has come to be known in all civilized lands by its original provincial name, loess; the assemblage of glacial deposits is everywhere known by the simple Anglo-Saxon designation, drift,—and only less widely by its British synonym, till; the foundation upon which all these categories of superficial deposits rest is universally recognized as rock, and a score of subordinate divisions are named by every school boy; yet the most extensive category of superficial deposits, of the phenomena lying nearest to man, is without a general name though many of its subdivisions are named—for here civilized man has imitated the savage, who names the members of a class but feels no need of a name for the class itself.

It is the more singular that the widespread products of rock decay should remain without distinctive appellation since at one period in the growth of geologic science such a designation was proposed and found its way into geologic literature. Early in the present century J. André De Luc clearly discriminated, first the solid rocks of the earth and the unconsolidated materials by which these rocks are mantled, and second, (a) the immediate products of rock decay in situ and (b) the débris transported and redeposited by streams. For the former portion of the superficial mantle he adopted the provincial designation for "earth" in Holland and northern Germany ("geest"*), and for the transported materials of all kinds he adopted the term "alluvium."† Soon after, De Luc's term came into use by geologists in this country; and by two of the foremost among them, Amos Eaton and T. Romeyn

* *Abrege Geologique*, Paris, 1816, p. 121.

† *Ibid.*, p. 112.

Beck, the unconsolidated mantle of superficial deposits was divided into the proper unmodified soil, called geest, and that which has been conveyed from a distance by water and exists in thick beds, called "alluvium."* Both Eaton and Beck pointed out that in extent and volume the geest far exceeds alluvium. But they lived in an age of speculation; the alluvial deposits offered an attractive subject for reflection and the thoughts of domestic and foreign geologists were concentrated upon them; cataclysms and deluges were in all men's mouths and minds, and before the pendulum of current thought had swung to mid position there came the glacial theory to once more distract attention from an inherently important subject; and the simple taxonomy and definite nomenclature of the pioneer geologists were forgotten in the race for knowledge concerning other and subordinate classes of deposits.

The provincial term adopted by De Luc and introduced into American literature by Eaton and Beck is in itself meaningless, and is thus an unobjectionable denotative term; it meets a manifest need of the tongue; it has never been supplanted; it has a definite place in literature, and it seems well to restore it.

REVIEW OF RECENT GEOLOGICAL LITERATURE.

United States Geological Survey, Twenty-first Annual Report to the Secretary of the Interior, 1899-1900, in seven parts. CHARLES D. WALCOTT, Director. *Part VII. Geography and Geology of the Black and Grand Prairies, Texas, with detailed descriptions of the Cretaceous Formations and special reference to Artesian Waters.* By ROBERT T. HILL. Pages 666; with 71 plates (including seven folded, maps, profiles, etc., in a pocket of the cover), and 80 figures in the text. Washington, 1901.

The region here reported comprises about 50,000 square miles, mostly in east central Texas, and thence extending into the southern part of the Indian Territory. Its southern end is at Austin, and thence it reaches north and northeast to the common corner of Texas, the Indian Territory, and Arkansas. The chief rock formations of the surface, chalky sands, marls, clays, and limestones, range from the beginning to the end of the Cretaceous period. They are almost horizontal,

* *Geol. Survey of the County of Albany*, 1820, p. 31; Cf. *Geol. and Agl. Survey, Rensselaer County*, 1821, p. 23.

but have prevailingly a slight dip to the southeast, toward the Gulf coast, somewhat exceeding the average surface slope, which declines from about 1,500 feet at the west to 400 feet at the east above the sea level.

From paleontologic studies of this development of the Cretaceous system in Texas, Mr. Hill finds it "divisible into two great groups or series, each of which in turn is composed of many beds of rock. The lower of these series begins with the Trinity sands and ends with the Denison beds, and has been named the Comanche series, after the town of Comanche, where the writer, when a boy, first studied these formations. The upper series begins with the Woodbine formation and extends through the Navarro beds; this has been termed the Gulf series. Each of the series represents a complete cycle of sedimentation and is initiated by an arenaceous littoral terrane."

A running summary of the fifteen formations making these Lower and Upper Cretaceous series, aggregating together about 4,500 feet in thickness, is given as follows: "The lowest Cretaceous formation (1) resting on the Paleozoic rocks and outcropping at the surface in the belt of Western Cross Timbers consists of loose beds of friable sand (locally called pack sand), with a few pebbles at its base (the Trinity sands). These sands pass upward into (2) light-colored arenaceous clays and marls in which alternating layers or beds of firm limestone of varying texture and thickness gradually appear. The marls and limestones are the Glen Rose beds. Another thick bed (3) of pack sand (the Paluxy sands) succeeds the Glen Rose beds. The outcrop of the Paluxy sands is covered with timber. Above the Paluxy sands are (4) clays alternating with thin limestones, usually accompanied by vast numbers of fossil oysters. These, the Walnut beds, pass upward into (5) white chalky limestones (the Comanche Peak beds), which are very fossiliferous and which usually constitute lower slopes of the escarpment of flat-topped mesas or plains. The Comanche Peak beds are distinguishable from the succeeding bed (6) of white chalky limestone (the Edwards limestone) only by the superior hardness of the latter, which is the rock of the numerous flat-topped buttes of the western border of the Grand Prairie and in which, at least south of the Brazos, are numerous beds of flint. The limestone, which is not very thick along the section under consideration, is succeeded to the east by another group of beds making the surface formations of the dip plains of the Grand Prairie between the western scarp rock and the Eastern Cross Timbers and consisting of alternations of marls and indurated layers of limestone. The lowest beds of this group consist of (7) darker-colored clays (the Kiamitia clays) containing great quantities of another fossil oyster. Above these appear more bands of limestone strata (8) of a chalky white color, alternating with clays (the Duck Creek formation) in which huge ammonites a foot or more in diameter are found. Near the top of these alternations of marls is a group (9) of whitish limestone beds (the Fort Worth limestone) in which limestones and marls alternate with great regularity. Fort

Worth is built on this formation. Above the Fort Worth limestone are beds (10) known as the Denison beds, which are mostly composed of clays, with frequent hard layers of impure limestone. These have ferruginous colors, such as chocolate, brown, and red, instead of the whitish lines which mark the preceding formations. The Denison beds pass into the western border of the Eastern Cross Timbers, where they are succeeded by another sandy timber-covered formation (11), the Woodbine, consisting of loose brown sand somewhat resembling the Trinity sands lying at the base of the whole section, but differing in particulars which are elsewhere described. In the upper part of these sands thin layers of blackish bituminous clay begin to alternate with the sand. Gradually the sand decreases and the clay increases until the latter makes the entire formation (12), the Eagle Ford. With the initiation of these black clays prairie lands again appear. The clays finally pass upward into a great formation of chalky limestone (13), the Austin chalk. This formation, upon which the city of Dallas is located, is some 500 feet thick. The chalk in turn passes upward into marly clays of great thickness, consisting in their lower part of unctuous, laminated, light blue and yellow clays (14) which are known in Texas as 'joint clays,' and which we shall call the Taylor marl. These clays underlie the main Black Prairie for a distance east of the longitude of Dallas. The whole of the Black Prairie east of the Austin chalk is composed of soft, unconsolidated beds, but those above the Taylor marl are characterized by sandy layers, alternating with the clays, and especially by minute specks of glauconite. The sands and clays of this character, which constitute the final formations of the Cretaceous, are found along the eastern margin of the Black Prairie and may be called the Navarro beds (15). The Navarro beds are blacker and more arenaceous than the Taylor marl. The small laminae of glauconitic sand in the Navarro beds give to them a greenish-yellow color in places. There are also some thin indurated bands of glauconitic sandstone and chalk marl in their upper portion."

After the detailed descriptions of all these Cretaceous formations, the following generalized observations of their physical or lithologic characters in relation to the stratigraphy and fossil faunas are stated:

"The paleontologic zones persist in horizontal extent regardless of changes in lithologic nature of the matrix.

"The beds vary in lithologic composition along horizontal lines toward or away from original shore lines of deposition.

"Similar lithologic character diagonally transgresses time horizons. ... Thus it is that everywhere at the base of the Cretaceous system there is a continuous bed of sand, which, when considered as a formation, transgresses much of the range of Cretaceous time."

The flowing wells of this region vary in depth from 100 to 3,330 feet; and they also vary greatly in their water pressure, from those of feeble flow, as a gallon per minute, to spouters of seven hundred times as great supply. In 1897 the number of flowing wells reported in this great district was 458; and the reports showed 506 other wells

reaching horizons of artesian water, from which it did not rise so far as the surface.

W. U.

The Evolution of the Northern Part of the Lowlands of Southeastern Missouri. By C. F. MARBUT. The University of Missouri Studies, Vol. I, No. 3. Pages viii, 145-207; with six plates (one being a folded map on the scale of three miles to an inch). Columbia, Mo., July, 1902. Price, \$1.25.

An area of about 2,500 square miles is described in this memoir, including the lowlands west of the Mississippi on both sides of the northeastern part of Crowley ridge, and of its continuation, beyond a space of interruption, by the Benton ridge. The geologic formations, in descending order, comprise Recent alluvium, of great extent, forming the surface of the lowlands; Pleistocene loam and loess; Lafayette gravels, sands, and clay, referred to the closing part of Tertiary time; and Paleozoic rocks, limestones and sandstone, of Trenton and Calcareous age. After the Lafayette period, the country was uplifted, and the Lafayette deposits were greatly eroded. This time of uplift seems to the reviewer to be correlative with the principal part of the Ice age farther north. During the later depression of the land, which seems to me referable to the closing part of the Ice age, being indeed the cause of its decline, "the mantle of Loess was deposited over the uneven surface, filling the valleys and building the land up nearly to its level before the preceding erosion. Then followed uplift and erosion to the present condition of the country. Late in the history of the region slight oscillations occurred producing terraces, but they were not sufficient in amplitude to interrupt the continuity of the cycle." Erosion after the deposition of the loess reached much deeper than the present lowlands, and they have been subsequently built up to their present levels with sandy alluvium. A very interesting and complicated history of the stream changes is traced during the vast work of erosion in the thick deposits of the valley drift, and during the recent upbuilding of the alluvial tracts.

In this greatest watercourse of our continent, the volume of modified drift very far exceeded its deposits in the Connecticut and Merrimack valleys of New England, where this part of the drift was earliest studied; but the conditions of its deposition, in the closing stages of the Glacial period, and of its speedily ensuing re-excavation, leaving remnants as plains and terraces, or in the Mississippi valley as long and wide ridges, above the alluvial bottomlands, were of the same character in both regions, and are our most important records of Late Glacial and Postglacial time.

Professor Marbut has well supplemented, for this region about the north end of the Crowley ridge, the description of its continuation more than a hundred miles south into Arkansas, which was given by Call and Salisbury in the second volume of the Annual report of the Arkansas Geological Survey for 1889. The deposition of sediments in the lower Mississippi valley derived from the waning northern ice-sheet was evidently of vast amount; their erosion in southeastern

It thus is intended to be a complete compend and *vade mecum* for ready use by lecturers and writers and for the independent student who desires to investigate any geological subject—at least so far as the same may have been already investigated and published by others.

N. H. W.

Bidrag till Kannadomen om Trilobiternas Byggnad. af. Joh. Chr. Moberg [Aftryck ur geol. foren i Stockholm förhandl Bd. 24. H. 5, 1902.]

From a fine example of *Nileus armadillo* Dal. the author is enabled to show the point of attachment of the muscles of the antennæ, hypostome, epistome, and several limbs of this species. He also remarks upon the nature of the compound eyes which have 3-4,000 facets. In this connection he takes exception to the opinion of the late G. Lindström that the "maculæ" on the hypostome carry organs of vision, and that the earlier Olenidæ were blind.

Dr. Moberg compares the system of radiating canals in front of the eyelobes and glabella in the Conocoryphidæ with the liver impressions in *Limulus*, and refers to the presence of these radiating impressions in *Elyx* and *Harpides*, and even in the Olenidæ. He remarks on the importance of an organ which is plain in a few blind forms, but has left no trace in the majority of the trilobites.

Considerable space is given to the description of a problematical organism apparently related to the graptolites. The paper is illustrated by one text figure, and a plate showing the head of *Nileus armadillo* and the problematical graptolite.

G. F. M.

Animals before man in North America, their lives and times. By FREDERIC A. LUCAS, Nov. 1902, pp. 1-291, 6 full page illustrations and 64 text figures. Appleton & Co., Price \$1.25 net.

A year ago, Mr. Lucas presented in popular form some of the ascertained facts of "Animals of the past" as they probably appeared in the flesh, and of their habitations. This book has been well received and is now supplemented by the one cited above. In the earlier work, the author dealt with extinct vertebrates, and these were described in groups according to affinity or association. In the present account both invertebrates and vertebrates are treated and the species are arranged chronologically, but not strictly so, thus enabling the writer to more readily keep alive the interest of the reader. About 80 pages are devoted to introductory matter and the invertebrates, while the balance of the book treats of the vertebrates with which Mr. Lucas is entirely familiar. Some of the chapter headings are "How the history of the past is read," "The era of invertebrates," "Great salamanders and their associates," "Dragons of sea and air," etc.

Mr. Lucas, among American scientific men, stands nearly alone as an author endeavoring to popularize some of the many intensely interesting facts concerning the geological antiquities dug out of the earth by paleontologists. How successful his books are to be with

the general public, time alone will demonstrate, but from the standpoint of accuracy of statement, Mr. Lucas' account is as good as present knowledge and one author can make it. It may be that in the future, the great popular books on scientific subjects will be prepared by a symposium of specialists, and then edited by some master teacher as John Fisk or John Lord.

To the average reader, the vertebrates will long remain as the most interesting forms of extinct life because of their resemblance to animals familiar to him, or because of their greater complexity of structure and size. In the chapter "Dragons of sea and air," the reader is told of fishes 20 feet long, turtles that weighed in the flesh about 2 tons, sailing reptiles having spread of wings 20 feet across and which in life did not weigh more than 25 pounds, and of a Dinosaur having 1600 teeth. On page 229 we are told that Brontosaurus had two pounds of brain to twenty tons of flesh, and on page 163 that man has about the same weight of brain to one hundred pounds of total mass.

In the chapter entitled "The rise of the mammals," a short but interesting account of the Titanotheres is given with two good drawings of heads of the oldest and most recent species as they appeared in the flesh. Another interesting chapter is the one entitled "The life of yesterday" in which the reader is told of the derivation and migration of such familiar brutes as the horse, mastodon, mammoth, bison, bear, etc.

The typography and printing are excellent, but the small cost of the book prevents elaborate illustrations and but few new figures are added. However, all of the illustrations are from good to passable excepting one designated "Devonian fishes" which has been badly mutilated in cutting down the plate made for Hutchison's book, "Creatures of other days." A slip of the pen occurs on page 92 where Postdam sandstone of Cambrian time is used in place of Catskill sandstone of the Upper Devonian.

C. S.

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CORRESPONDENCE.

ADDITIONS TO THE LIST OF NICARAGUA VOLCANIC ERUPTIONS IN HISTORIC TIME. On reviewing the list of volcanic eruptions and earthquakes in Nicaragua—mailed to you on 28th June 1902—I fear that I overlooked a few important ones—as follows:

1609. *Momotombo*, in violent action accompanied by severe earthquakes, lasting for several days, covering to a depth of several feet with ejecta the ancient city of Leon, then the capital of Nicaragua, at the N. W. base of the volcano, on the western margin of lake Managua: The capital was removed to the present site about 40 miles to the S. of W. and about 18 miles from the Pacific ocean: Fragments of records of this eruption also of the marriage there in 1608 of the cacique of the Ameriques were in the archives of the "Palacio Episcopale" in the present city of Leon in 1890.

1648. *Strong earthquakes* in western Nicaragua, doing much damage to the then new city of Leon, killing several persons and injuring many: These earthquakes were probably from Momotombo.

1651. *Earthquakes* very violent in western Nicaragua.

1663. *Earthquakes* in series, very violent, destroying houses and lives that were near to volcano Momotombo and westward to the Pacific; also violent about the city of Granada on western side of lake Nicaragua: *The cause* of that series of earthquakes also elevated the bed of the Rio San Juan, the outlet of the waters of lake Nicaragua,

so as to afterwards (unto the date of this letter) prevent the navigation of that river by vessels of size sufficient to transport cargoes between Cadiz, Spain, and Granada, at the west margin of lake Nicaragua, also between Cuba and Granada. Nicaragua: Ayon's "History of Nicaragua"—(the only reliable history of the country published) tells, Vol. 2, chap. vi, pp. 64 65, of a "ship that was in the lake Nicaragua during the several earthquakes of 1663, that had come loaded with merchandize from Cuba; that after the earthquakes and rise of the bed of San Juan river, near its exit from lake Nicaragua, never succeeded in getting out of the lake—altho endeavoring to do so several times."

It is probable that transportation of ships across Nicaragua would have ceased—for a month or so—until the elevation of about one-fourth of the length of the bed of the Rio San Juan had been dredged to a proper or to its former depths. No fissures are to be found in, across, or near that river.

J. CRAWFORD.

WORK OF THE CORNELL SUMMER SCHOOL OF FIELD GEOLOGY. During the four past summer seasons, Prof. G. D. Harris of Cornell University has conducted a series of geological expeditions which have been very beneficial to the students who have taken the work and also been the means of adding not a little to the accurate knowledge of New York stratigraphy.

Thoroughly believing in field work for beginners as well as for advanced students, professor Harris owns and keeps in repair two gasoline launches that the best service possible may be given to the expeditions. By this means the party has (1) access to all the various water-ways of the state, (2) means for transporting camp materials, fossils, &c., and (3) a means of travel free of charge.

Two classes of students have availed themselves of the opportunities, viz., beginners in geology who wish to see the country and learn how detailed work is done, and those more advanced, graduate students, instructors, &c., who have wished to apply themselves to some particular problem and work it to completion. For the latter class all the machinery of the department is at hand. Camp is pitched to stay till the field work on such particular problems is done. The beginners are given tramps over the region until they are familiar with the topography, and then they are asked to help in the detailed work. If this program seems unfair to the beginning class, it is only necessary to state that the beginners of one season become the producers of the next.

The first trip was in 1899. Professor Harris took five men in one of his launches on a four week's trip through the different water-ways of the state. In 1900 permanent camp was pitched at Trenton Falls and side trips were taken to lake Champlain and through the Mohawk valley via the Erie canal. It was during this season that a new fauna was found in the Calciferous of the Mohawk valley. Dr. H. F. Cleland, now professor of geology at Williams, described this new fauna in Bulletin No. 13 of "Bulletins of American Paleontology". A topographic map of the region was made by Mr. A.

C. Veatch now on the U. S. Geological Survey, which also appeared in the same publication.

In 1901, with headquarters in the Helderberg Mts., three side trips were taken, viz, lake Champlain, as far as Plattsburg, down the Hudson to Rondout, and the Erie canal back to Ithaca.

The major part of the detailed work of this season was done in the Champlain valley. Mr. P. E. Raymond, now fellow in geology at Yale, worked out the Crown Point section and during last year published the results as No. 14 "Bulletins of American Paleontology". He also during that summer began work on the Chazy limestone on Valcour island.

In 1902 camp was again in the Helderbergs. Mr. Raymond continued his work on the Chazy of Valcour island. The Bryozoa he sent to Yale where he is now working on them, and his other material he sent to Cornell where he expects to work again in the near future.

In the Helderbergs, six weeks were spent in a detailed study of the geology of the region. Spirit level lines were run by professor Harris from the newly established bench mark at East Berne (U. S. G. S.) around through all the sections studied in detail, to the N. Y. State Survey triangulation station on top of Countryman hill, a distance of at least 12 miles. All lines were run in duplicate. The exact height of each contact line in each section can now be referred to mean ocean level.

Extensive collecting and minute stratigraphic work at Countryman hill and Indian Ladder sections occupied the major part of the time of the more advanced workers.

Miss Mignon Talbot, now working over her material at the State University of Ohio, spent with aids about six weeks on the Countryman Hill section, while the writer with more or less assistance spent an equal amount of time on the geology of Indian Ladder; the material collected, he is working up at Cornell. The combined work will shortly appear in printed form.

The last three weeks of the season were spent at Oriskany falls. Professor Harris made a detailed topographic map of the region on a scale of 1 in. to 500 feet, and the section was carefully worked by Mr. Joviano Pacheco, who had charge of the Water Lime group, and Mr. Joviano Pacheco, who was responsible for the Lower Helderberg rocks.

Mention too should be made of the trip on foot from New Salem to Oriskany Falls in company with Dr. H. F. Cleland whereby we quite carefully worked a number of sections through the Helderberg formations, noting variations in thickness, lithological characters, and faunas. This trip made a connecting link between the work at the Helderbergs and Oriskany Falls. A Bulletin will be forthcoming on the Oriskany Falls section.

On the way back to Ithaca, stops were made at Manlius and Union Springs.

CHAS. E. SMITH.

PERSONAL AND SCIENTIFIC NEWS.

THE HAYDEN MEMORIAL MEDAL for 1902 was conferred by the Philadelphia Academy of Natural Science on Sir Archibald Geikie.

PROF. J. F. KEMP AND DR. E. O. HOVEY were recently elected respectively chairman and secretary for 1903 of the section of geology and mineralogy of the New York Academy of Sciences.

NATURAL GAS was developed recently by a well at Heathfield, Sussex, England, the capacity being fifteen million cubic feet per day. This is situated 46 miles from London, and the gas is derived from the Kimmeridge clays.

PROF. A. W. GRABAU, of Columbia University, on Nov. 19 gave a public address at the College of Physicians and Surgeons, New York, on "Illustrations of the law of Tachygenesis, or acceleration of development."

DR. F. A. WILDER late of the Iowa survey has recently been appointed state geologist of North Dakota and professor of geology at the State University. The survey is an adjunct to the department of geology in the State University, located at Grand Forks.

GEOLOGICAL SOCIETY OF WASHINGTON. At the meeting on November 12th the following program was presented: "Titanic iron ore from Wyoming," Waldermar Lindgren; "Mineral vein formation in Yellowstone Park," W. H. Weed; "A reconnaissance in the Mt. McKinley region, Alaska," Alfred H. Brooks.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE will hold its fifty-second annual meeting at Washington, D. C., Dec. 27 to Jan. 3. The "affiliated societies" number twenty-two and they will hold meetings at Washington the same week. Section E, (Geology) of the Association will hear the address of Prof. W. M. Davis, of Cambridge, Mass., who will also preside over the Section. The Geological Society of America will be presided over by Prof. N. H. Winchell, Minneapolis, who will give the annual presidential address. This society will meet in the hall of the United States Geological Survey. Prof. Winchell will discuss the question: *Was Man in America in the Glacial period?*

MR. R. A. BLAIR died at his home in Sedalia, Mo., on the 18th of October. He had not been in good health for 6 months and finally, after an illness of something like two weeks, died. He was about 60 years old.

For over 25 years he spent nearly all his leisure in studying the rocks of central Missouri, particularly the beds of the Burlington and the Chouteau limestone. He made a large collection of fossils, but generously gave them away. His cousin, Sam Miller of Cincinnati, Ohio, described and figured many of the fossils found by Mr. Blair. He was a good collector and probably collected more Chouteau fossils than anyone else. He was a member of the State Board of Mines and Geology from 1889-1890. His wife died in 1901. He leaves one daughter, Miss Jessie Blair. G. C. BROADHEAD.

PROFESSOR W. H. HOBBS recently presented (Oct. 20) a paper to the New York Academy of Sciences which was accompanied by a wealth of detailed observations on the geology of Manhattan island, condensed as follows by the secretary, Dr. E. O. Hovey:

In his introduction the author called attention to the unusual opportunities now offered for studying the geology of Manhattan island through the numerous great engineering projects now being carried forward. The waterways surrounding Manhattan island are deep cañons, with a depth of nearly 200 feet in the East river and 300 feet or more in the North river, now partly filled with drift deposits the amount depending on the velocity of the tidal currents.

In 1865 Stevens advanced the theory that the river channels were along lines of faults ("longitudinal and transverse fractures"). Newberry regarded the East river as the lowest reach of the Housatonic river before it discharged its waters into the Hudson, which was then the outlet of the Laurentian series of lakes, and he considered the Harlem river with Spuyten Duyvil creek a smaller tributary of the Hudson.

Dana believed that the relatively easy solution of certain beds of limestone determined the position of the river channels. This view of Dana's has been supported by Kemp and Merrill, while Gratacap rejects the theory advanced by Stevens.

Professor Hobbs finds that no correspondence can be established between the directions of the belts of limestone or dolomite and of the New York water front, except within the stretch from Kingsbridge to Macomb's Dam bridge. Along this line too the observed facts point to the occurrence of a narrow strip of limestone dropped down between nearly vertical faults. The sections of the Harlem river which are furnished by the bridges across it show clearly that it is not a simple erosion valley resulting from cutting by the stream. The bed of the stream is marked by sudden changes of level, and the Harlem seems to have chosen its course quite independently of the position of ridges of the harder gneiss. Under the East river limestone has been found at but two localities,—under the channel east of Blackwell's island and in one of the drill holes underneath the Manhattan pier of

East river bridge No. 3. The limestone east of Blackwell's island is enclosed between parallel fault walls, and appears to have been dropped down along them. The numerous occurrences, however, of gneiss and gneiss only along, in and under the East river leave little doubt that the main portion of the bed is composed thereof.

Regarding the bed rock beneath the North river, comparatively little is known, but the origin of its channel is sufficiently accounted for by its position along the contact of the Newark system with the crystallines. This contact seems surely to be a fault-border on account of its markedly rectilinear extension, the great scarp of basalt, the much inferior position of the newer terranes, and the borings along the route of the proposed tunnels of the Pennsylvania, New York and Long Island railroad company.

The author holds that the directions of the channels of Spuyten Duyvil creek and Harlem and East rivers have been determined largely by lines of jointing and displacement. Manhattan island borders directly upon the Newark area, in which the existence of a network of faults has been established by the work of several observers, and the network probably extends beyond the limits of the area. The striking rectilinear outlines of the island, especially of the northern half of it, and its topographic development are favorable to the view that it represents an orographic block left standing between downthrown strips of the crust. The rectilinear gorge of the upper Harlem between Washington Heights and Fordham Heights is continued, so far as its western wall is concerned some two and a half miles south of the river. It is parallel to the direction of the scarp of the Palisades, and of the Hudson. Besides the cross fractures indicated by the different parts of the Harlem river, which were pointed out by Stevens, several other cross fractures on and about Manhattan island were pointed out by the same author. Dana also considered that the Manhattanville cross valley was formed by a cross fracture. A considerable number of faults have been definitely established. Their directions correspond in general to the elements in the courses of the river channels. The exceptions to this rule are the fissures in the East river east and west of Blackwell's island.

The author cited a number of faults which have been disclosed by numerous borings and tunnels and in closing called attention to the fact that the buried rock surface in the lower part of the city (south of Twenty-third street), as well as that below the area of the Harlem flats (north of One Hundred Tenth street and east of Eighth avenue) is characterized by the most abrupt changes of level. In his opinion the area of these portions of the island represent orographic blocks depressed by faults, reefs of gneiss and limestone rising along the Harlem area, while reefs of gneiss alone characterize the southern district.

Professor Hobbs' paper was discussed briefly by professors Kemp, Dodge and Stevenson, and it was evident that the author's theory would not be accepted without considerable further investigation.

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